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Implementation of the production version of the performance and calibration modules of the MK 92 Mod 2 Fire Control System Maintenance Advisor Expert System

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Monterey, California

THESIS

IMPLEMENTATION OF THE PRODUCTION
VERSION OF THE PERFORMANCE AND
CALIBRATION MODULES OF THE MK 92
MOD 2 FIRE CONTROL SYSTEM
MAINTENANCE ADVISOR EXPERT SYSTEM

by

John L. McGaha

September, 1994

Thesis Co-Advisors:

Magdi Kamel
Martin J. McCaffrey

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The MK 92 Mod 2 Fire Control System (FCS) is a complex, maintenance intensive shipboard weapon system found primarily aboard the Oliver Hazard Perry class fast frigates (FFG-7). A maintenance advisor expert system (MAES) is being developed by the Port Hueneme Division of the Naval Surface Warfare Center and the Naval Postgraduate School (NPS) to assist the Fire Control Technicians aboard ship to better isolate faults in the MK 92 Mod 2 FCS.

This thesis furthers the efforts of the project at NPS by investigating key hardware and software implementation issues that involve the deployment of the MAES to the fleet. Additional deployment issues addressed in this thesis include software documentation, integration of Performance and Calibration Modules, and the feasibility of the MAES being used as a training aid.

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IMPLEMENTATION OF THE PRODUCTION VERSION OF THE PERFORMANCE
AND CALIBRATION MODULES OF THE MK 92 MOD 2 FIRE CONTROL SYSTEM
MAINTENANCE ADVISOR EXPERT SYSTEM

by

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Submitted in partial fulfillment of the requirements for the degree of

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September, 1994

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ABSTRACT

The MK 92 Mod 2 Fire Control System (FCS) is a complex, maintenance intensive shipboard weapon system found primarily aboard the Oliver Hazard Perry class fast frigates (FFG-7). A maintenance advisor expert system (MAES) is being developed by the Port Hueneme Division of the Naval Surface Warfare Center and the Naval Postgraduate School (NPS) to assist the Fire Control Technicians aboard ship to better isolate faults in the MK 92 Mod 2 FCS.

This thesis furthers the efforts of the project at NPS by investigating key hardware and software implementation issues that involve the deployment of the MAES to the fleet. Additional deployment issues addressed in this thesis include software documentation, integration of Performance and Calibration Modules, and the feasibility of the MAES being used as a training aid.

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I. INTRODUCTION

A. BACKGROUND

This thesis is a part of an expert system development project, the Maintenance Advisor Expert System (MAES) for the MK 92 Mod 2 Fire Control System (FCS), undertaken by faculty and students at the Naval Postgraduate School (NPS). This thesis furthers the efforts of the development, and initiates the efforts for deployment, of by investigating the key issues surrounding the implementation and integration of MAES.

The MK 92 FCS is complex and maintenance intensive. It can be intimidating and overwhelming to the enlisted Fire Control Technician (FC) responsible for maintaining and repairing the system. It is reported that this system involves significant trouble isolation efforts, requires frequent technical assistance in fault isolation, and has a one-to-four ratio of unnecessary part replacement (Powell, 1993).

As long as the MK 92 FCS, based on 1970's technology, remains the key weapon system for the Oliver Hazard Perry Class frigates, and the frigates continue to stay in commissioned service, the Navy is forced to commit resources to keep the system battle ready. Arleigh Burke once said,

If the equipment doesn't work in battle, it doesn't make much difference how much else the officers know, the battle is lost.

B.   OBJECTIVES

The objective of this thesis is threefold. First to refine, update, and integrate the

Performance and Calibration Modules developed in an earlier effort. Second to implement

a production version of the Maintenance Advisor, and third to develop a Maintenance

Advisor Maintenance and User's Manual.

C.   RESEARCH QUESTIONS

This thesis seeks to answer one primary and four subsidiary research questions. The

questions listed below, begin with the primary research question.

1. What are the production version implementation issues for diagnostic expert
    systems?

2. What are the implementation issues for fielding the Maintenance Advisor from a
    software developer perspective?

3. What is the feasibility for use of the Maintenance Advisor System as a training aid?

4. What are the required procedures for implementing new diagnostic software and
    associated hardware to the fleet?

5. What hardware is best suited for implementing the Maintenance Advisor aboard
    ship?

D.   SCOPE

This thesis focuses on the implementation issues encountered during the MAES life

cycle phase that is between development and the deployment of the production version.

The scope of the author's task is developing a production version of the MAES for

deployment. The task is accomplished by addressing software and hardware

implementation issues, integrating the MAES software modules, creating documentation, and packaging the program.

E.   METHODOLOGY

Prerau claims that an expert system development cycle involves three distinct phases: Initial, Core Development, and Final Development and Deployment. (Prerau, 1993) The MK 92 MAES project follows this methodology and the project is currently in the Final Development and Deployment phase. This thesis closely follows the final development and deployment methodology that is recommended by Prerau.

F.   ORGANIZATION OF THE STUDY

This thesis is divided into six chapters, followed by five appendices, which are organized in the following manner:

Chapter II - Expert System Fundamentals: This chapter discusses expert system definition, structure, applications, benefits, limitations, and development.

Chapter III - MK 92 Mod 2 FCS Maintenance Advisor Expert System (MAES): This chapter contains a brief description of the MK 92 Mod 2 FCS, its maintenance personnel, maintenance support, and maintenance manuals. The chapter covers the background of the MAES and its potential benefits to the U.S. Navy. The chapter concludes with the status of the MAES project.

Chapter IV - Hardware Implementation Issues: This chapter answers the subsidiary research question, "What hardware is best suited for implementing the MAES aboard ship?" This is done by discussing the hardware requirements for deploying the MAES,

addressing issues that impact the hardware decision, comparing portable and desktop computers, and recommending a deployment computer.

Chapter V - Software Implementation Issues: This chapter answers a subsidiary research question, "What are the implementation issues for fielding the MAES from a software developer perspective?" The chapter discusses user interface issues, software development and deployment issues, the transfer of the MAES to the maintainers, user training and integration of MAES aboard ship, and program documentation.

Chapter VI - Conclusions: This chapter contains a summary of the author's conclusions on the production version implementation issues for the MAES. The chapter also discusses the a survey used to gather feedback from the users, and answers a subsidiary research question, "What is the feasibility for use of the MAES as a training aid?"

Appendix A - Oliver Hazard Perry (FFG 07) Ship Information: This appendix lists all of the Oliver Hazard Perry (FFG 07) ships that are in commission. The tables group the ships geographically.

Appendix B - MK 92 Mod 2 FCS MAES Prototype 1.0 User's Manual: This appendix contains the user's manual that accompanies the MAES Prototype 1.0 program aboard the USS SIDES (FFG-14) and at the Fleet Training Center, San Diego.

Appendix C - Notebook Computer Technology: This appendix summarizes current notebook computer technology.

Appendix D - MK 92 Mod 2 FCS MAES User's Survey: This appendix contains the survey that accompanies the MAES Prototype 1.0 aboard the USS SIDES (FFG-14) and at the Fleet Training Center, San Diego. It will provide the project team data needed to measure the user's acceptance, and performance of the MAES.

Appendix E - MAES Prototype 1.0 Installation Files: This appendix lists the contents of three primary script files required to install the MAES Prototype 1.0 using a professional software installation tool.

II. EXPERT SYSTEM FUNDAMENTALS

A.   OVERVIEW

This chapter provides a brief overview of expert system technology. It begins by defining what an expert system is, followed by a discussion of the components of an expert system. Two example applications of expert systems, diagnostics and instructional, are discussed in the following section. The process of developing expert systems is discussed next. The last two sections discuss the potential benefits and potential problems of expert systems, respectively.

B.   WHAT IS AN EXPERT SYSTEM?

An expert system is a computer program that conveys the knowledge and reasoning of a human expert, formulated by facts and heuristics, to one or more users that do not possess that knowledge (Bowerman, 1988). Facts are usually obtained from manuals and other written documents, while heuristics, the strategies or rules of thumb that experts use in problem solving, are found only in the mind of experts, who acquired and developed them through years of experience. For example, before replacing a failed integrated circuit card, an expert diagnostic technician may know to first extract, thoroughly clean the card connectors, re-seat, and then re-test the circuit card.

C. STRUCTURE OF EXPERT SYSTEMS

An expert system has three basic parts: a knowledge base, an inference engine, and user interface. The components of an expert system are depicted in Figure 2-1.
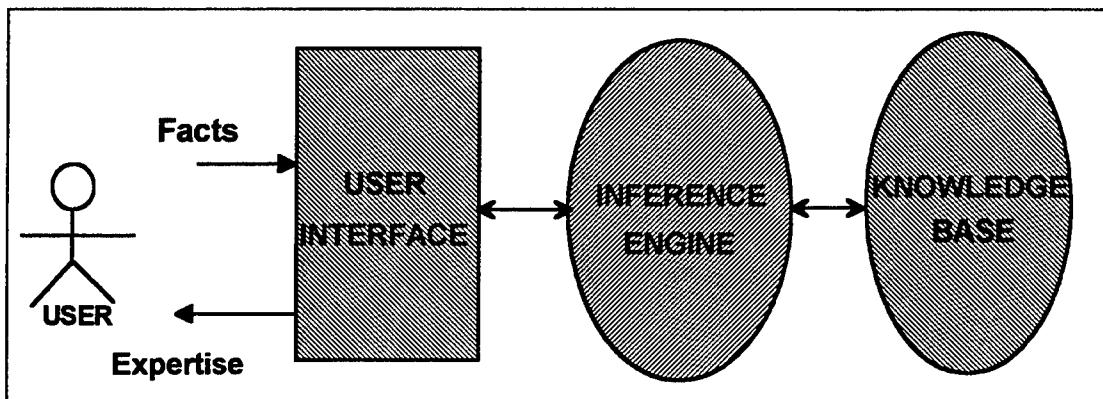
Figure 2-1 Expert System Structure

1. Knowledge Base

The knowledge base is the portion of the expert system that contains the knowledge domain, specifically, the facts and heuristics that comprise the domain of the expert (Prerau, 1990). The knowledge base is accessed by the inference engine to provide expertise for solving a problem.

2. Inference Engine

Inference is defined as an implied relationship of one object to another, allowing new facts to be derived from existing ones. The inference engine is the part of the expert system that contains the general problem solving knowledge, thereby controlling the system by combining stored knowledge with knowledge introduced into the system by the user, to derive new knowledge (Prerau, 1990).

3. User Interface

The user inputs data (facts) to and receives expertise from the expert system through the user interface. The expert knowledge base is what the user seeks from an expert system. The user must be able to obtain that knowledge easily and in an understandable form. Therefore the design of the expert system's user interface is paramount to the overall system's acceptance.

D. APPLICATIONS OF EXPERT SYSTEMS

Some of the most common characteristic uses of expert systems can be combined into generic categories. These categories include interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instruction, and control (Waterman, 1986). Only two categories, diagnosis and instruction, are discussed in this section.

1. Diagnostics

Expert systems used in diagnostic applications make inferences about the most probable cause or causes of system malfunctions, based on system behavior characteristics or situation descriptions by the user (Waterman, 1986). Some examples of diagnostic expert systems are locating faulty components in complex electronic circuitry, diagnosing medical conditions, or isolating the source of engine failure in a sophisticated U.S. Army tank. This type of expert system usually interacts with users who answer the system's questions or information requests, and who act on the expertise provided by carrying out recommended courses of action.

2. Instruction

Expert systems designed for instructional purposes teach students how to operate complex equipment, complete difficult administrative functions, and perform medical procedures (Waterman, 1986). This type of expert system compares the user's knowledge with a stored knowledge base, analyze the difference, and provide the user with the knowledge necessary to eliminate the difference.

E. DEVELOPING EXPERT SYSTEMS

The development cycle of an expert system includes three basic phases: (Prerau, 1990)

- ◆ An initial phase involving management approval, project team formation, domain selection, and selection of hardware and software tool.

- ◆ A core development phase which involves acquiring, representing, and implementing the knowledge.

- ◆ A final development and deployment phase which encompasses building and deploying a production system.

Only a brief discussion of the core development phase is presented in this section.

1. Knowledge Acquisition

Knowledge acquisition is the process of obtaining the knowledge of an expert, documenting that knowledge, and testing the knowledge. It is regarded as the most intricate, time consuming, and the bottleneck of system development. The knowledge may be acquired through personal interviews, surveys, or any number of methods of correspondence.

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2. Knowledge Representation

Once the knowledge to be used in the expert system application has been acquired, the next step in the core development cycle is to represent that knowledge. The knowledge may be represented by using one or more artificial intelligence (AI) paradigms. These paradigms include rules, frames, semantic networks, and procedures. The paradigm selected provides the basis for knowledge implementation.

3. Knowledge Implementation

Knowledge implementation is the process of implementing the acquired knowledge into an expert system program using a suitable language or expert system shell. The process follows a cyclic implementation model which includes running test cases after knowledge has been implemented, and if representational or programming errors are discovered, cycle back to the knowledge representation process. (Prerau, 1990)

F.   BENEFITS OF EXPERT SYSTEMS

The benefits of experts systems are numerous, often unique to individual applications, but most expert systems have at least three common benefits: cost savings, preserving knowledge, and improved training.

1. Cost Savings

Human expertise is expensive, often scarce, and expires when the expert possessing that expertise leaves the organization. In contrast, expert systems are inexpensive and reside permanently with the organization (Waterman, 1986). Expert

systems may initially have high development costs, but that cost is offset by higher organizational productivity and lower operating costs.

Diagnostic applications in particular offer the greatest potential for cost savings by reducing equipment repair time which in turn reduces equipment down-time, and may decrease the chance of incorrectly or unnecessarily replacing non-failed components. For example, a rule-based expert system, called XCON, developed by Digital Equipment Corporation (DEC) to assist in management of DEC's complex manufacturing environment reportedly saved approximately $15 million the first year it was in use (Turban, 1990).

2. Preserving Knowledge

Another important benefit provided by expert systems is preserving knowledge. As experts leave an organization, they take with them a significant amount of experience and knowledge that may be irreplaceable. Expert systems capture this knowledge and experience for continued use long after the expert is gone. The preserved knowledge then becomes corporate knowledge, which could be passed down throughout the organization to lesser experienced personnel.

3. Improved Training

Although some expert systems are designed exclusively for training purposes, all expert systems offer improved training opportunities to the users. A successful example of an expert system used for training enlisted personnel in diagnostic procedures is located at the Navy's Close-In-Weapons-Systems (CIWS) School. The benefit of training from

the expert system is available at any time the system is being used. A person using an expert system gets a sense, through the explanation facilities included in the system, of having a human expert working with him, teaching and sharing new or vaguely familiar knowledge.

G. LIMITATIONS OF EXPERT SYSTEMS

Expert systems are not a panacea. They suffer from a number of limitations which include not being taken seriously, over dependence on their advice, failure to recognize their limitations, and being perceived as a threat.

1. Expert System Not Taken Seriously

An expert system may not be taken seriously by any level in an organization. Such a situation would have a negative impact on the system's effectiveness, reducing the use and or acceptance of the system. The system may be viewed as a toy, an experiment or just another burdensome program to maintain. This attitude is not uncommon and may be compounded by lack of proper documentation, training, and user support (Beerel, 1993). The problem can be avoided or at least minimized by careful implementation and proper indoctrination and training of each level in the organization.

2. Over Dependence on Expert Systems

In contrast to the system not being taken seriously, the user may become too dependent on the expert system, which may happen if the expert system proves to be a valuable asset to the user. Over dependence may result in stagnation of innovative ideas of the users, the user failing to use his own intuition or training, and in the case of

diagnostic applications, may result in the user avoiding use of basic troubleshooting techniques and reference to technical manuals. Proper indoctrination during the deployment of the system and training, can reduce this problem.

3. Failure to Recognize Limitations of Expert Systems

Some users may tend to believe that an expert system will have solutions to all of the possible problems which may be encountered by the user. Clearly, this is not the case. Users should be made aware that technology can not solve every potential problem occurring because of the exponential number of variations a problem will have. In addition, the user must realize that imperfect humans were tasked with acquiring, representing, and implementing the knowledge which is integrated into the expert system.

4. Expert System may be Perceived as a Threat to Experts and Users

An expert may be reluctant to provide the knowledge needed to build an expert system if he feels threatened by the development of the system. It is reported that experts in several diverse fields would not fully participate in the development of expert systems in their field of expertise. Similarly, an expert system may be perceived as a potential replacement of the user (Carr, 1992). Like the other potential problems, this problem can be avoided or reduced through proper education and training.

H. SUMMARY

An expert system is a software program that captures and distributes human expert knowledge for use by other people. The structure of an expert system contains three components: a knowledge base containing the expert's knowledge, an inference engine

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which manipulates that knowledge, and an interface for the user to interact with the system. There are numerous applications of expert systems. These include diagnostic and instructional applications. The life cycle of an expert system has several distinct phases. The core development phase of the life cycle discussed in this chapter, includes acquiring, representing, and implementing the knowledge. Potential benefits of expert systems include cost savings, preserving knowledge, and improved training. Limitations of expert systems include expert systems not taken seriously, over dependence on expert systems, failure to recognize limitations of expert systems, and expert systems may be perceived as a threat to experts and users.

The next chapter discusses background information on the MK 92 Mod 2 Maintenance Advisor Expert System.

III. MK 92 MOD 2 MAINTENANCE ADVISOR EXPERT SYSTEM

A. OVERVIEW

This chapter presents background information of the MK 92 Fire Control System (FCS). Section B briefly provides a basic description of the MK 92 FCS, while Section C provides a detailed discussion of the MK 92 FCS Mod 2. Section D discusses the purpose, origin, development requirements, development cycle, and expert system implementation tool for the MK 92 Mod 2 Maintenance Advisor Expert System (MAES). Finally, Sections E and F discuss the potential benefits of MAES and the status of the project, respectively.

B. BASIC DESCRIPTION OF THE MK 92 FIRE CONTROL SYSTEM

The MK 92 Fire Control System (FCS) is a multi-purpose system that can acquire, track, and engage air, surface and shore targets simultaneously. It is based on 1970's technology with several systems still in use today.

The first implementation of the MK 92 systems were installed aboard United States Navy hydrofoils (PHMs) and United States Coast Guard (USCG) cutters and were designated MK 92 Modification (Mod) 1 FCS. While all of the PHM class ships containing the Mod 1 versions have been decommissioned, it is still aboard 25 USCG cutters. (Powell, 1993)

The next generation of MK 92 FCS was designated as Mod 2 and installed aboard the U.S. Navy Oliver Hazard Perry class guided missile frigates (FFGs) and six frigates in the Royal Australian Navy. Fleet personnel refer to this class of ships as the FFG-7, pronounced "fig sevens". The Mod 2 systems include capability to use the FCS to launch a type 1 standard-missile (SM-1) using the MK 13 Guided Missile Launcher System (GMLS). The fleet refers to this launcher as the "one-armed bandit".

The latest and last version of the MK 92 FCS is Mod 6. This version contains solid state technology which was not available during development of the two earlier versions. There are currently 11 Mod 6 type ships in the fleet. Appendix A lists both the Mod 2 and Mod 6 ships in commissioned service today.

C.   MK 92 MOD 2 FIRE CONTROL SYSTEM

1. System Description

The MK 92 Mod 2 Fire Control System (FCS) is the heart of an integrated shipboard system that includes separate radars: AN/SPS-49 Air Search Radar and AN/SPS-55 Surface Search Radar. The two search radars are located on the mast and are shown, together with the other MK 92 FCS Mod 2 external components, in Figure 3-1. The remote search radars scan the horizon in 360 degree rotations and provide the FCS with contact information consisting of air and surface targets.

The main components of the MK 92 Mod 2 FCS are illustrated in Figure 3-2. The figure shows where the external video from the AN/SPS-49 and AN/SPS-55 radars

enters the FCS. The interface with CAS and STIR is depicted as well as weapon control paths to the gun and missile launcher.

The FCS can track air and surface targets simultaneously. It also gives the ship fast reaction capability against up to four incoming targets with the following combinations: two air and two surface targets, one air and three surface targets, or four surface targets. (Sperry, 1979)
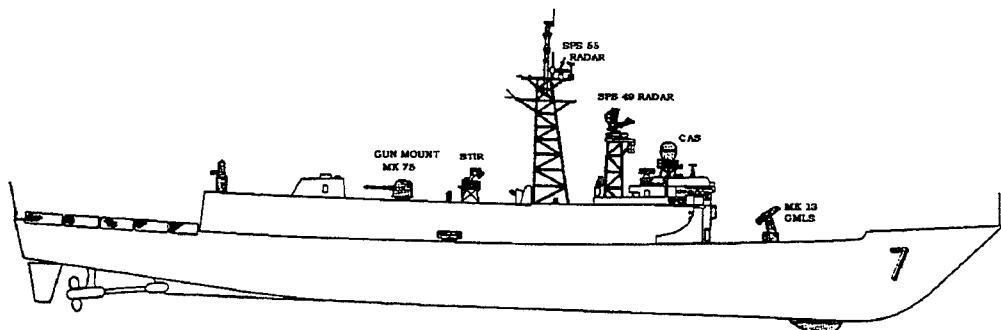
Figure 3-1. Oliver Hazard Perry Class Frigate

The normal operational mode for the FCS is remote designation of incoming air targets. Acquiring and tracking the designated air targets is accomplished through the use of either of two unique FCS antennas: Combined Antenna System (CAS) and Separate Track Illuminating Radar (STIR). Target acquisition and tracking may also be accomplished without a remote designation by means of local control of the FCS. Air targets may also be exchanged between the STIR and CAS antennas. The CAS antenna systems contains a combination of an air/surface track and missile guidance antenna with

an air/surface track while-scan antenna. The CAS and STIR antennas are depicted in Figure 3-1.

Information from the radars is processed by the FCS in order to solve the fire control problem. Before ordnance can be delivered to a target; i.e., a gun can be fired or a missile launched at a target, the FCS must know the target's speed, elevation (for air targets only), range, and relative position to the ship. Once this is information is processed by the FCS computer, a calculation is made predicting the position of the target in the immediate future with respect to the ship parameters. Once a target is successfully tracked, engagement with the gun or missile system may be accomplished.

To engage a target, the target's predicted position is transmitted to the 76mm gun or the MK 13 GMLS. The 76mm gun is fully automatic and capable of firing 80 projectiles before reloading is necessary. It and can be used to engage air and surface targets as well as provide shore bombardment capability. As stated, the MK 13 GMLS launches SM-1s which may be launched against either surface or air targets.

Engagements by the FCS are made using one of four internal Firing Channels (FC): FC1, FC2, FC4, and FC5. (Note: FC3 does not exist.) Air targets are engaged by only one of two channels, FC1 or FC2. These air targets may be engaged using the gun or missile. Likewise, surface targets may also be engaged with a gun or missile via FC1 or FC2 channels. However, FC4 and FC5 are the normal channels for surface engagements and are gun engagements only. The firing channels are summarized in Table 3-1.

Figure 3-2 MK 92 Mod 2 Fire Control System Basic Configuration Diagram

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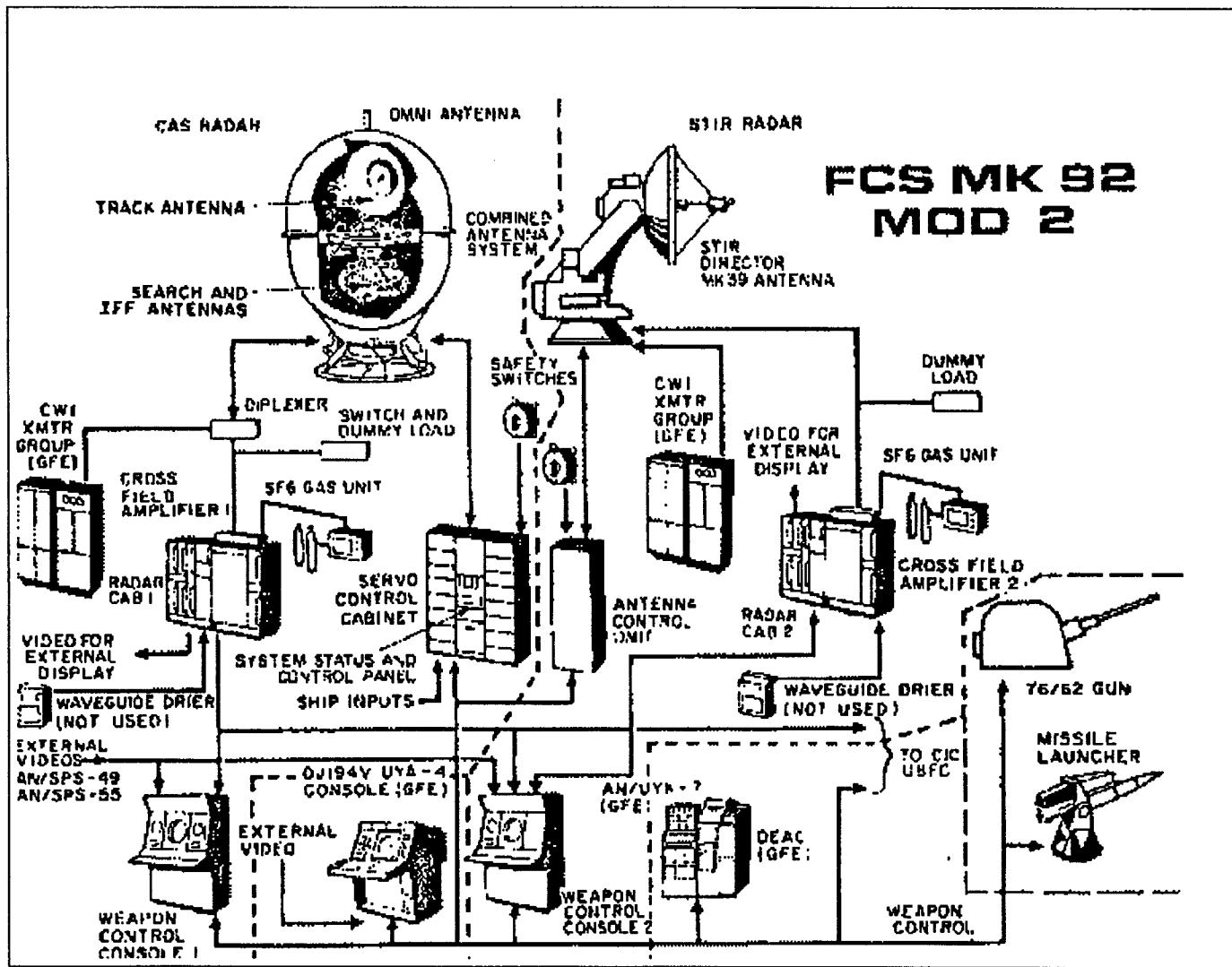
FIRING CHANNEL	ANTENNA	WEAPON	TARGET ENGAGED
FC1	CAS Track	Gun or Missile	Air or Surface
FC2	STIR Track	Gun or Missile	Air or Surface
FC4	CAS Surface Track While Search	Gun only	Surface
FC5	CAS Surface Track While Search	Gun only	Surface

Table 3-1 Firing Channel Summary

2. System Testing

Firing Channel performance, CAS and STIR sensitivity, CAS and STIR transmitter power, DSOT initialization, and calibration tests are the main tasks performed using the Maintenance Requirement Card (MRC).

In order to ensure the FCS will track and engage targets as designed, comprehensive testing and maintenance is required. The MK 92 Mod 2 has built-in test facilities: automatic on-line fault monitoring and a computer program used for Daily System Operability Tests (DSOTs). The DSOT is the primary means of computer generated testing of the FCS. The DSOT simulates the steps involved in processing a target from initial acquisition through engagement. All primary circuits are exercised during this test and the operator is alerted if a failed condition (NO-GO) exists.

The DSOT, as its name implies, is conducted daily, and takes one fire control technician approximately one hour to complete. The specific actions required by the technician are listed on the MRC. There are six major sections of the MRC used to conduct the DSOT and are as follows:

- STIR transmitter RF power checks

- CAS transmitter RF power checks

- DSOT test initialization.

- FC-1, FC-4, FC-5 designation, acquisition, and tracking test.

- FC-2 designation, acquisition, and tracking test.

- CAS/STIR receiver sensitivity tests.

If a NO-GO condition results during the DSOT, the technician should stop the test and commence isolating and correcting the casualty condition. A basic flow of casualty recognition and isolation is depicted in Figure 3-3. It can take from several minutes to several days to isolate and repair a NO-GO condition in a complex weapon system such as the MK 92 FCS. Needless to say, a FCS that is in a NO-GO state degrades the ship's operational readiness and may place the ship in danger if it is in a hostile environment.
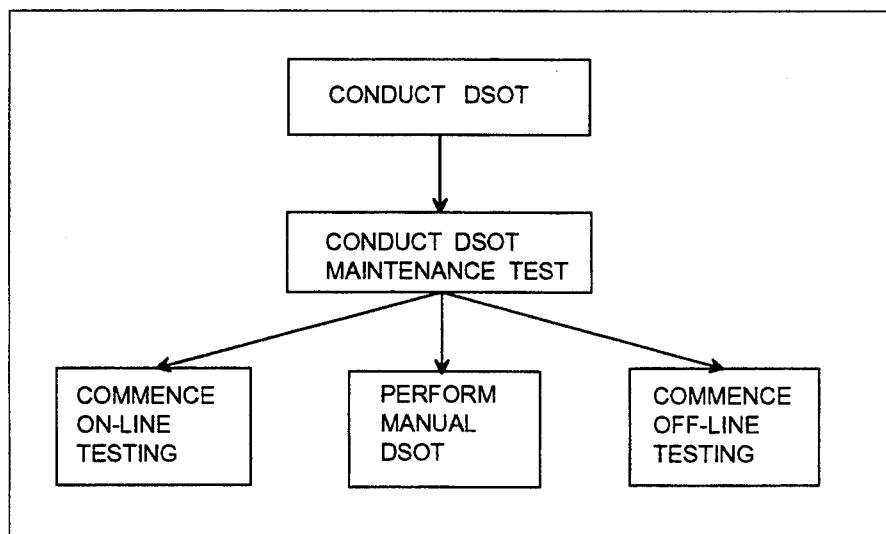
Figure 3-3 Problem Recognition Flow Analysis

Off-line testing often requires the expertise of technical representatives from Mobile Ordnance Technical Unit (MOTU) or Naval Sea Systems Command (NAVSEA). (Technical assistance is described in a following section.) The MK 92 FCS has a reputation for requiring extensive maintenance and is very costly to operate. Documented casualty reports (CASREPs), required to be submitted to the ship's squadron, group, and type commanders when a ship has a casualty which reduces her operational readiness, show that technical assistance from outside activities is required for many system casualties. For example, during a recent five quarter period, over 40 percent of the casualties reported via CASREPs requested outside technical support to isolate the cause of equipment failure.

The MK 92 technicians often isolate the casualty to a particular circuit card that appears to be defective. The defective circuit cards must be given to supply personnel when a replacement is received. The defective cards are then returned to the original manufacturer for repair. Numerous cases of "no fault evident" (NFE) of the returned cards have been reported. (Powell, 1993) The same report found that the Navy spent almost $1.5 million in maintenance funds unnecessarily replacing perfectly good parts.

3. Maintenance Personnel

System testing and maintenance is conducted aboard ship by enlisted personnel. Technicians that operate and maintain all versions of the MK 92 FCS are enlisted Fire Control Technicians with a Navy Enlisted Classification (NEC) 1102. The technicians receive this NEC once they have successfully completed MK 92 FCS School. The school,

located in San Diego, California, is a 32 week intensive training course. Students receive classroom instruction and "hands on" system maintenance and diagnosis. Budget cuts and military downsizing have forced the other school located in Dam Neck, Virginia, to close at the end of fiscal year 1993.

The number of maintenance technicians available to man ships is controlled by Enlisted Personnel Management Command (EPMAC) in New Orleans, LA, and is dependent upon ship type. As of June 1993, the manning level for Fire Control Technicians holding NEC 1102 aboard active FFG-7 class ships is seven. It includes one chief petty officer, one petty officer first class, and five junior petty officers. Reserve FFGs have one less junior petty officer than the active ships (Powell, 1993). However, reserve and active ship manning levels vary constantly and many do not have a chief petty officer or enough junior petty officers. Lack of proper manning levels in the fleet is one of the major contributing factors for the high number of technical assistance requests.

4. Maintenance Support

The maintenance personnel aboard ship are not left unsupported to face difficult casualties and complicated maintenance procedures. Technical support is available to the technicians from NAVSEA and MOTU. A ship may request technical assistance by telephone or more commonly via a casualty report (CASREP) to the respective type commander's (TYCOM) Readiness Support Group (RSG). RSG makes the determination whether to task MOTU or NAVSEA with assisting the ship requiring assistance. MOTU is usually the first choice because they are more cost effective than NAVSEA. The reason

is that Naval enlisted personnel with applicable NECs compose a technical assist team from MOTU while higher paid senior civilian personnel make up the team from NAVSEA.

Consolidation of the 14 MOTU sites world-wide commenced in fiscal year 1992. Current plans will merge existing MOTUs with NAVSEA support activities by the beginning of FY 95 (Sims, 1994). This merger will save money and reduce bureaucracy, but it may also mean reduced technical support to the fleet's technicians (Ursich, 1994).

5. Maintenance Manuals

Both shipboard and technical support personnel rely on maintenance documentation to isolate and repair NO-GO conditions. Since the technical experts typically have years of diagnostic experience on the MK 92 FCS, they tend to rely more upon their accrued knowledge and less on technical manuals. In contrast, shipboard personnel are younger with less experience and must rely on technical manuals.

The original technical manuals distributed for all MK 92 Fire Control Systems are in a series called Ordnance Publications (OP) and Ordnance Documents (OD). The old manuals were developed in several volumes under three distinctly numbered publication series: OP 4300, OP 4302, and OD 46576. These technical manuals were superseded in 1989 with manual series SW271-C2-MMO. Fleet distribution of the new manuals began in early 1990. The new manuals consists of two specific volumes in 23 parts: Volume 1 has five parts and Volume 2 has 18 parts. Additionally, a four part series of illustrated parts breakdown (IPB) manuals and a single installation and alignment (INM) manual is

included in the new set. They are designated as SW271-C2-IPB and SW271-C2-INM, respectively.

In an effort to reduce paper aboard ship and aid technicians, NAVSEA Data Support Activity (NSDSA) located at the Naval Surface Warfare Center (NSWC) in Port Hueneme, California, is converting technical manuals to digitized media. The manuals are raster scanned and stored on a digitized compact disk (CD). A computer software, called Advanced Technical Information Support (ATIS), is used to view both text and illustrations of the digitized manuals.

Technical information is collected and digitized by ship class. Once all the technical manuals for the entire ship class are digitized, ships receive the CDs, ATIS software, and hardware to access the digitized technical manuals. The software costs $350.00 per copy and is pre-installed on the multimedia desktop computer system provided to each ship by NSDSA at no cost to the ship.

The MK 92 Mod 2 FCS technical manuals for of the FFG-7 class ship have been digitized and is now in distribution to the fleet (Leetus, 1994). All of the Mod 6 FFGs have ATIS software and hardware installed (Whitaker, 1994). Tables A-1 through A-4 in Appendix A list the Mod 2 and Mod 6 FFGs that have the ATIS package. The tables include each ship's homeport and coast or operating area.

D. MAINTENANCE ADVISOR EXPERT SYSTEM (MAES) BACKGROUND

This section presents background information of the MK 92 Mod 2 Fire Control System (FCS) Maintenance Advisor Expert System (MAES). The first three sections

discuss MAES's purpose, origin, and development requirements, respectively. Section 4 briefly discusses the scope of the project. Section 5 discusses the development cycle, including knowledge acquisition, representation, and implementation, and Section 6 discusses expert system tool implementation.

1. Purpose

The main purpose for developing the MK 92 FCS Maintenance Advisor Expert System (MAES) is to enhance the ability of the Fire Control Technicians to better determine, diagnose, and resolve problems occurring within their systems without the assistance of outside technical representatives. It should be noted that MAES is not intended to replace technical experts, rather to free their time for more complex ones. If technical assistance is required after the technician has used MAES, the amount of time a technical representative spends onboard ship will be reduced because the technician using MAES will already have eliminated numerous casualty possibilities.

2. Origin

The conception of the Maintenance Advisor began at the Port Hueneme Division (PHD) of the Naval Surface Warfare Center (NSWC), Port Hueneme, California, in 1991, and development began internally in January 1992 (Powell, 1993). Faculty members of the Naval Postgraduate School (NPS) were asked in the fall of 1992 to assist in the development and implementation of the system (Seto, 1994).

Efforts by faculty and students at NPS originally focused on evaluating and selecting an expert system shell, reviewing all knowledge documents, and representing

expert knowledge in a suitable knowledge representation scheme for implementation using an expert system shell.

3. Development Requirements

The requirements for implementing MAES were specified by engineers at PHD and were promulgated to cognizant faculty members at the Naval Postgraduate School. These requirements are:

* System developed using off-the-shelf (COTS) software.

* Applications development tools and the MAES must be easy to use.

* Interface for MAES must be graphically based.

* Expert system shell and MAES must be interoperable with a database.

* Knowledge base must draw from all available MK 92 Mod 2 FCS technical documentation, established troubleshooting techniques, casualty data, and expert reasoning.

4. Scope

The scope of the expert knowledge is the troubleshooting diagnosis, and resolution of casualties discovered during the MK 92 DSOT. Specifically, this includes RF power checks for STIR and CAS transmitter; performance checks which include FC-1, FC-2, FC-4, and FC-5 designation, acquisition, and tracking tests; and calibration conducted during CAS and STIR receiver sensitivity tests.

5. Development Cycle

The core phase of development cycle of the MAES discussed here is acquiring, representing, and implementing the knowledge needed to develop the expert system. Testing and evaluation of the program is considered to be the final part of the

development cycle, but is not discussed here. A master's thesis by Timothy Tutt and Kent Dills, completed in September 1994, conducted this phase of the development cycle (Tutt, 1994).

a. Knowledge acquisition/representation

Knowledge acquisition is a process of obtaining the knowledge of an expert, documenting that knowledge, and testing the knowledge. The initial knowledge base for the MAES, developed by Mr. Dorin Sauerbier of Paramax under contract by NAVSEA, was represented as a series of troubleshooting charts or diagnostic trees. Mr. Sauerbier used his expertise and MK 92 Mod 2 FCS publications to develop the knowledge trees for Performance and Calibration Modules of DSOT.

Figure 3-4 is an example of a diagnostic knowledge tree for the Designation Time function of the Performance Module.

The diagnosis of the function begins at the root of the tree at the node labeled A. The first step requires the technician to provide an error signal to servos with the antenna disabled. The second step requires him to check if the voltage at the output of the D/A converter UD441A2G1/CO4 is 7VDC. If the answer is yes, he proceeds along the right branch of the tree, else he proceeds with the left side. The traversing of the diagnostic tree may lead to another knowledge diagnostic tree or to a conclusion instructing the technician to replace a particular component. Numbers at the lower left corner of the nodes are the expert's notation for indicating to the developer that an associated help function is to be attached to this instruction.

28
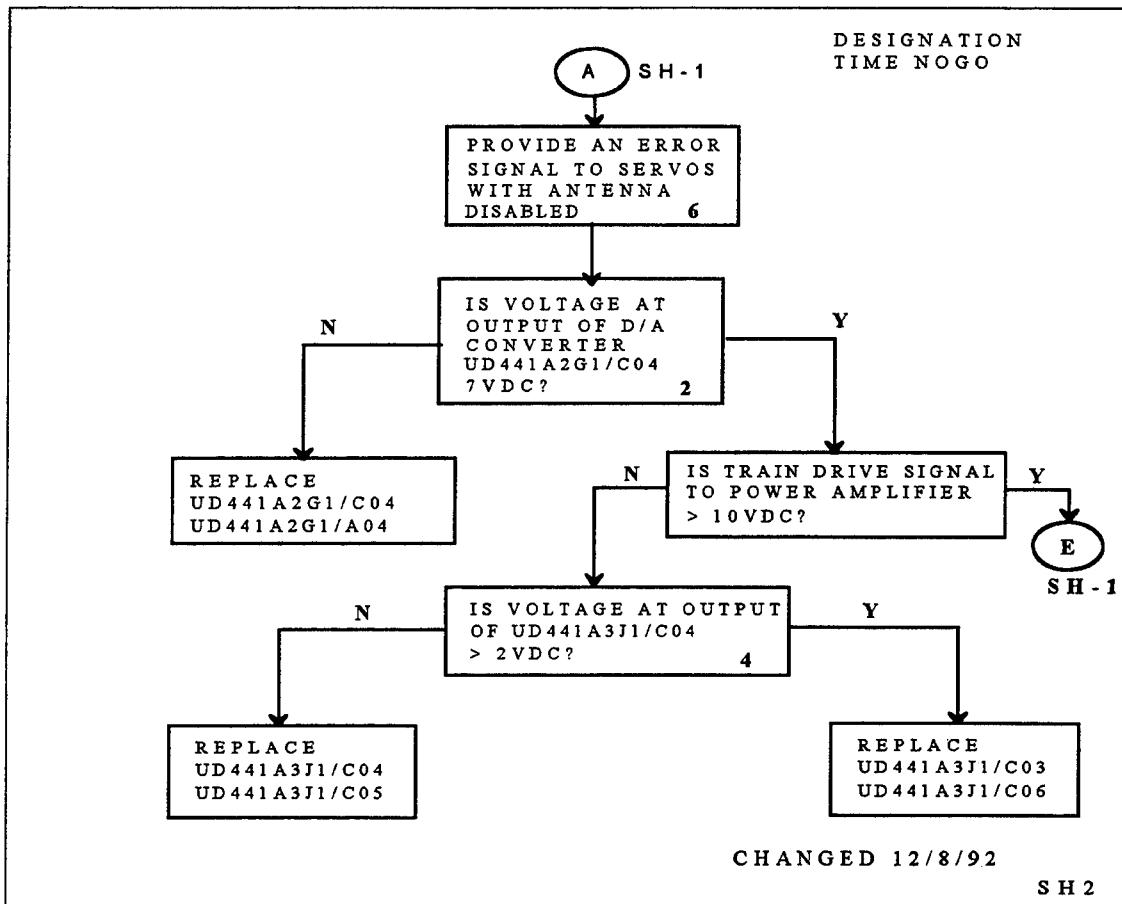
Figure 3-4 Knowledge Diagnostic Tree

b. Knowledge implementation

Knowledge implementation is the process of implementing the knowledge acquired using suitable programming language or expert system shell. Once the represented knowledge was received, the development team at NPS began implementing the knowledge using a visual expert system shell from Symbologic called Adept.

Figure 3-5 shows how the knowledge diagnostic tree in Figure 3-4 is implemented as an Adept procedure. The procedure mirrors to a great extent the diagnostic tree developed by the expert. The second node from the top of the diagram

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causes a display to be presented to the technician, instructing the user to provide an error

signal to servos with the antenna disabled, and prompting him or her to answer the

question "Is the voltage of D/A Converter 7 volts DC?".
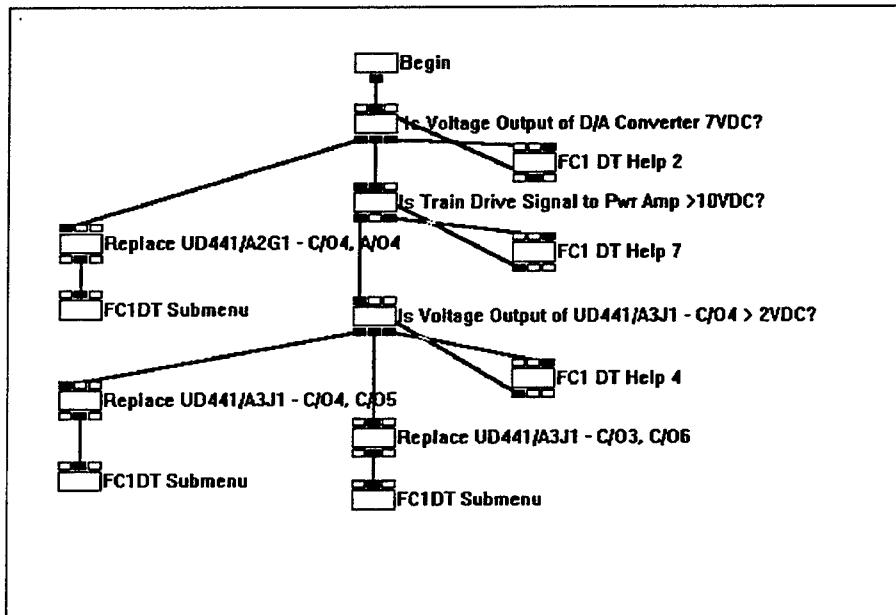
Figure 3-5 Adept Procedure Diagram

If the user answers "yes", the node evaluates to true and control is passed to the

node connected to the display node via a true arc. In this case it is the node directly

below. If the user answers "No", the node evaluates to false and control is passed to the

node connected to the display node via the false arc. In this case the node to the left,

which instructs the user to replace a specific circuit card. A third option associated with

the display is a Help button which when selected provides the user with detailed

information on how to perform the procedure specified.

6. Expert System Tool Implementation

As indicated, a visual expert system shell from Symbologic called Adept, is being used to develop MAES. Adept was selected because of its ease of use, built-in GUI capabilities, low cost, and its provision of unlimited run-time license for the Microsoft Windows 3.x environment. Other Adept features include: a built-in scripting language for creating program scripts, built-in functions, and an integrated visual debugger.

Adept combines object oriented programming with expert system capabilities. Adept is the first expert system on the market to use a procedural approach rather than a rule based one. Adept has a procedure based inference engine that supports backward chaining (goal directed reasoning) and forward chaining (result or data directed reasoning). The inference engine can execute up to 32 procedures. This technology was developed at the Stanford Research Institute during research on NASA's space shuttle. Adept uses visual nodes and color coded arcs to represent the knowledge manipulation and flow.

The project started with the use of Version 2.11 and has been upgraded to Version 2.2. The original cost of Adept Version 2.11 was $695.00 per copy with an unlimited run-time license. Version 2.2 which costs $795.00, was provided to NPS at no charge as an upgrade from the previous version. The upgrade for NPS still includes an unlimited run-time license, but new buyers are required to pay a run-time license fee.

E.   POTENTIAL BENEFITS OF MAES

Use of an expert system is well suited for diagnosis of complex electronic systems like the MK 92 FCS. A recent economic evaluation found that the Navy should take advantage of the benefits of developing and implementing an expert system for the MK 92 FCS. The following benefits are the results of Powell's research . (Powell, 1993)

1. Repair Parts Savings

Powell reports that during fiscal year 1991, over $900,000 was spent replacing unnecessary parts. Over 22 percent of the parts turned into the supply depot were perfectly good parts with no fault evident (NFE). He estimated that potential savings are predicted to be $775,000 in maintenance costs over the life of the system (12 years) once the MAES is deployed to the fleet.

2. Reduced Reliance on Outside Technical Assistance

It is reported that 50 percent of the MK 92 Mod 2 FCS documented casualties required technical assistance, of which 10 percent required the technical representatives to travel. These travel expenditures amounted to over $93,000. Powell estimated that the use of MAES can result in a $17,000 annual savings in technical representatives travel.

3. Improved Shipboard Training

MAES will increase the technician's overall knowledge in troubleshooting techniques and MK 92 FCS operation. Training is a benefit that is hard to quantify. Technicians using the MAES will learn to approach problem solving the way an expert does. MAES gives numerous "How" and "Why" help information throughout the

program. By reading the procedures and steps that are contained in these help windows, the user will gain new knowledge about the system or have his own knowledge reinforced.

F.   PROJECT CHRONOLOGY

The following is a chronology of thesis efforts undertaken to develop the prototype. A master's thesis by Steve Powell, completed in September 1993, conducted an economic analysis of the benefits of the MAES. The analysis concluded that considerable economic savings can be realized by the deployment of the system.   Annual savings predicted include: $700,000 in repair parts, $118,959 in shipboard man-power, and $17,000 in reduced technical assistance travel time (Powell, 1993).

Two master's theses by Clinton Lewis (Lewis, 1993) and Claude Smith (C. Smith, 1993), completed in September 1993, implemented the initial Performance Module of the system. The implementation incorporated the expert knowledge of all firing channel parameters related to Performance checks that are tested during DSOT.

A master's thesis by Michelle Smith (M. Smith, 1994), conducted in September 1994, restructured the original Performance Module by using structured design and programming techniques. It also implemented new knowledge received from the knowledge expert, since the completion of the earlier prototype.

A master's thesis by David Geick and Steve Mikler (Geick, 1994), completed in March 1994, implemented the initial Calibration Module of the system. A feasibility prototype of the Calibration Module was demonstrated to PHD in January 1993, and required requested additions and modifications were incorporated in the prototype.

A master's thesis by Timothy Tutt and Kent Dills (Tutt, 1994), completed in September 1994, tested, validated, and verified the knowledge contained in the Calibration Module, and recommended a test plan to be followed in further testing of the module.

A master's thesis by Susan Talley (Talley, 1994), completed in March 1994, developed a prototype parts database using Microsoft Access Version 1.1, and addressed the issues involved with interfacing this database with MAES. Due to compatibility problems, this feature will not be included in the initial implementation version of MAES, but will be included when a newer version of Adept resolves the inter-communication problem with Access.

A master's thesis by Paul Meisch (Meisch, 1994), completed in September 1994, addressed potential multimedia enhancements to the MAES. Multimedia capabilities will not be incorporated into the initial version of MAES, but will be considered in later versions of the prototype.

The next chapter discusses hardware implementation issues that were considered during the selection of a computer to deploy MAES aboard ship.

IV. HARDWARE IMPLEMENTATION ISSUES

A. OVERVIEW

This chapter addresses the subsidiary research question, "What hardware is best suited for implementing the MAES aboard ship?". This question is answered by discussing hardware issues (factors) considered during selection of a computer for deployment to a shipboard environment. The first section addresses the minimum hardware required to run the expert system and associated software. Other factors, which include portability, operating environment aboard ship, cost, procurement, expandability, accountability, and security are addressed in the following section. The chapter concludes with a comparison of portable computers and desktop computers, followed by a recommendation of what computer is needed for deployment of MAES to the fleet.

B. MINIMUM HARDWARE REQUIRED

The MAES is being developed on desktop IBM compatible computers, operating in Microsoft DOS 6.2 and Microsoft Windows 3.1 environment. The development computers have the following hardware characteristics: 486 central processing unit (CPU) running at 33 MHz, 8 megabytes (MB) of random access memory (RAM), a minimum of 120 MB hard disk storage, and VGA color monitors. The deployment hardware does not necessarily have to be exactly the same as the development hardware, but must be capable of operating MAES at acceptable performance levels.

The initial hardware recommendation for deployment was a portable IBM, or compatible, computer with a 486 CPU (Powell, 1993). Since this recommendation, newer technology has

been developed, prices of faster and more efficient computers have been significantly reduced, and a broader spectrum of potential users of MAES have been solicited for their preferences of a computer.

The computer selected for deployment must have a large memory capacity to handle memory intensive Windows applications, enough disk storage to effectively store temporary Windows files and permanent programs, a sufficiently fast CPU to draw graphics and respond to calls to the database, a floppy disk drive for installing and backing up programs, a video graphics array (VGA) monitor capable of drawing the graphics contained in MAES, and a cursor positioning device to operate the graphical user interface.

Table 4-1 lists the minimum requirements of this hardware for MAES and associated software. The data represents software vendor's recommendations, extracted from applicable software user's manual. It represents the minimum hardware requirements to efficiently operate each of the software programs. It is important to note that this table lists the minimum values and does not represent the most efficient or desirable values.

Device	MAES Prototype 1.0	Microsoft Windows 3.1	Microsoft DOS 6.2	Symbologic Adept 2.2	Microsoft Access 1.1
CPU	80386	80386	80286	80386	80386
RAM	4 MB	4 MB	640K	2 MB	4 MB
Storage	12 MB (plus 20 MB for dB)	7 MB	7 MB	3 MB	13 MB
Drives	One HD floppy & Hard Disk	One HD floppy & Hard Disk	One HD floppy & Hard Disk	One HD floppy & Hard Disk	One HD floppy & Hard Disk
Monitor	VGA	VGA	EGA or VGA	VGA	EGA or VGA
Mouse or Trackball	Required	Required	Not Required	Required	Required

Table 4-1 Minimum Hardware Required to Support MAES Software

In summary, the minimum hardware requirements a computer must have to operate MAES and its associated software include: an 80386 CPU, 4 MB of RAM, 60 MB hard disk storage (does not include multimedia requirements for future enhancements), one high density (HD) floppy drive, a VGA monitor (color or monochrome), and a mouse or trackball.

C. ISSUES IMPACTING THE HARDWARE DECISION

This section addresses issues that impact the hardware decision and should be considered for the final selection. They include portability, commercial-of-the-shelf (COTS) versus ruggedized computers, operating environment, cost, procurement, expandability, warranties, accountability and security. In addition, fielding, maintenance and replacement issues are discussed. These issues must be considered when selecting the most desirable hardware for MAES.

1. Portability

The MK 92 Mod 2 FCS has its major components located in six primary areas of the ship. These areas are depicted in Figure 4-1. Both the STIR and CAS antennas are located on the exterior part of the ship and have associated equipment rooms inside the ship. The consoles that operate the MK 92 Mod 2 FCS are located in the ship's Combat Information Center (CIC). Other associated components, such as switchboards, are located in the Radio Information Computer Equipment Room (RICER).

The computer selected for deployment of the MAES must provide the technician aboard ship the capability to use the program's features when troubleshooting components in any of the six areas. The best way of achieving this requirement is by using a laptop or notebook computer that can be easily taken to any of these areas. An alternative is to use a desktop computer located

in one place. Instructions could be relayed to/from other locations by sound powered telephones.

A more in-depth discussion of each alternative is provided later in Section D of this chapter.
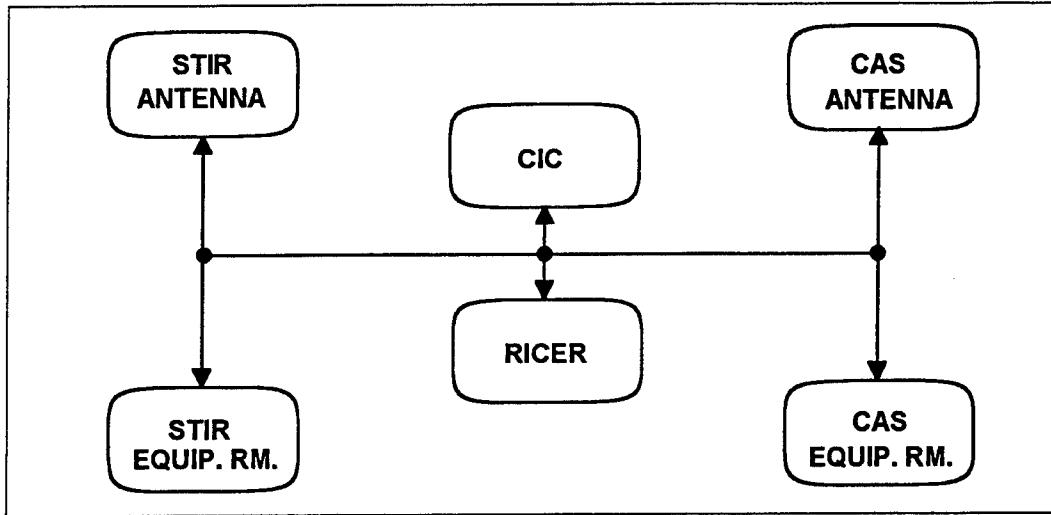
Figure 4-1 MK 92 Mod 2 FCS Component Locations Aboard FFG-7 Class Frigates

2. Commercial-Off-The-Shelf (COTS) Versus Ruggedized Computer

The procurement reforms proposed by DoD will change the way it currently purchases computers. Driven by the cost factor, DoD is recommending the use of COTS computers for its various commands. (Endoso, 1994)

The use of COTS desktop computers is widespread aboard Navy ships. Ship's purchase these commercial computers primarily for administrative purposes. The purchasing contracts discussed later in the chapter make it easy for ships to obtain COTS hardware at a competitive price. Laptop and notebook computers are also common aboard ship. In addition, many personnel aboard ship bring their own portable computer.

Ruggedized computers are used for special applications and are usually rare aboard ships, primarily because of their high cost. In the course of this research prices for ruggedized 486 computers ranged from $10,000 to $30,000 each. Most had active-matrix color screens. In evaluating alternatives for MAES hardware, it is evident that the Navy could buy several (perhaps

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as many as ten) COTS portable computers for every ruggedized portable. This is because ruggedized portable computers cost approximately ten times more than COTS portable computers.

MAES would not be the first system to use COTS equipment. Technicians presently have several different COTS items (such as multimeters and oscilloscopes) used for troubleshooting. Although no empirical data was available on the survivability of such equipment, the author's personal experience, both as an enlisted technician and officer, is that sailors take precautions to protect and take care of COTS equipment. They realize it is in short supply and valuable to them. Simple precautions (such as COTS carrying cases for the computers) should enhance their survivability.

Because of the significant cost differential (several COTS computers equal the cost of one ruggedized) COTS computers are recommended for the initial deployment aboard ships for the proposed quality management board (QMB) fielding. The fielding issues and QMB proposal are discussed in Chapter V. A ruggedized computer can better withstand the adverse environmental conditions discussed in the following section.

3. Shipboard Environment

A shipboard environment is a harsh environment that is not always conducive to the efficient operation of the vast array of electronic equipment onboard. This environment includes such conditions as electromagnetic interference (EMI), high heat sources, bright sunlight, frequent power surges, and exposure to corrosives[1]. A short discussion of each condition follows.

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[1]   The environmental issues discussed apply particularly to a portable computer. A desktop computer properly mounted in the STIR equipment room should only be exposed to frequent power surges.

a. Electromagnetic Interference (EMI)

Electromagnetic interference (EMI) is a phenomenon caused by electromagnetic waves, emanating primarily from radars and communication antennas, that affects the normal operation of other electronic equipment located in the immediate area.

Effects of EMI aboard ship are primarily confined to the exterior areas of the ship. The Navy reduces the adverse effects of EMI to the interior of the ship by constructing ships that have steel or aluminum walls (bulkheads), ceilings (overheads), floors (decks), and by placing armor shielding around electrical cables.

A technician using MAES on a portable computer to troubleshoot the STIR and CAS antennas would need to exercise caution because other shipboard antennas are capable of radiating high powered frequencies in the range of 200 Megahertz (MHz) to beyond 18 giga hertz. EMI emissions by other antennas can destroy magnetic information stored on disk drives, RAM, and the instructions embedded in read only memory (ROM) and the CPU (Wellteroth, 1993).

Some vendors manufacture ruggedized portable computers that withstand the effects of EMI. Martin Marietta discovered, during testing the effects of EMI on six portable computers, that only a ruggedized portable computer, priced at over $15,000, is unaffected by controlled levels of EMI (Wellteroth, 1993). It is unlikely other antennas/EMI emitters would be secured to allow a technician to work on MK 92 equipment. Therefore, the technician must be aware of the risks and take precautions to minimize potential damage.

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b. *High Heat Sources*

Prolonged solar radiation (sunlight) can be detrimental to a computer's performance because the CPU and other integrated circuit (IC) chips are highly sensitive to heat.

Temperature ranges between 41° to 95° Fahrenheit (F), and relative humidity between 20 to 80 percent, without condensation, are the normal operating parameters for most notebook computers.

Martin Marietta conducted solar radiation tests, in accordance with MIL-STD-810E Solar Radiation Test, on portable computers in prolonged sunlight. The portable computers tested had internal cooling fans (not usually available in most portables) and monochrome transflective LCD displays. Temperature was varied from 89.59° F to 116.60° F. As the temperature and solar radiation increased to 116.6° F, the computer display darkened and had to be continually adjusted for proper viewing. Above 116.6° F the displays became unreadable. Typical COTS portable computers will most likely operate at full capacity at lower temperatures.

Additional sources of heat include that emanating from steel decks and hot exhaust from the propulsion engines. Combined, these heat sources have the potential to cause extremely high temperatures inside a portable computer. This can lead to possible hardware failure. One remedy is to use a laptop that has low power and has some ability to dissipate heat (i.e., low wattage power supply with internal cooling fan) (Wellteroth, 1993). Only ruggedized computers have these features. Another potential factor in heat build-up comes from operating a portable computer from a carrying case for which no cooling is provided.

c. *Bright Sunlight*

The brightness of the sun affects the usability of a computer by creating reflections off the computer's screen. This can degrade the display or make it unreadable. Under such conditions, some improvement may be achieved by shielding or turning the computer away from direct sunlight. According to Wellteroth, the best remedy is to use a portable computer with a transflective LCD display. COTS portable computers, discussed in Appendix C, with active-matrix screens use transflective technology. In addition, screen readability in direct sunlight has been significantly improved over the past few years.

d. *Frequent Power Surges*

While battery life for portable computers has continued to improve over the past few years, and spare batteries are available at reasonable prices, it is anticipated that AC power will frequently be required. Power hookups are available at the six locations aboard ship where the MK 92 components are located.

Turbine generators, used to create electricity aboard ship, often lose power and cause power surges throughout the ships electrical distribution system (i.e., the 115 volts used by computers). Many hard-wired electrical and electronic equipment have the means to compensate for most power surges, but precautions must be taken for computers by connecting them to the 115 volt power source through a surge protector.

e. *Corrosives*

Ships are surrounded by water and air that contain high levels of salt. This is a highly corrosive environment to metal and electronic components and can cause component failure. Other corrosives in a shipboard environment include oil, grease, and hydraulic fluid. These

corrosives are more prevalent in exterior spaces of the ship. So the technician using MAES in those areas must take care to eliminate or reduce contact between these corrosives and the computer.

f. Movement and Structure

Because of sudden rolls and pitches of the ship, the computer used to implement MAES must have the capability of being securely fastened to a fixed structure on the ship. This avoids the possibility of the computer falling and suffering damage. Desktop applications are easier to securely fasten to structures on the ship than portables. It is possible to securely stow a portable computer in a ruggedized storage case. This approach is useful in that it provides extra protection when transporting it around the ship as well for general storage. However, the portable computer becomes vulnerable to the possibility of falling and being damaged when it is being used outside of its case. Finding a location for securing a portable computer in all the possible working areas will be very difficult.

4. Cost

The cost of computer hardware and associated software is continually in a downside trend due to breakthroughs in technology and ever increasing competition. While portable computers have historically been much higher in price than their desktop counterparts, recent trends have shown that the gap in narrowing.

Two major COTS computer vendors, IBM and Compaq, have recently reduced the price of some of their portable computers over 25 percent. IBM reduced the price of its ThinkPad line by as much as 27 percent to a price just under $1800. This is about the same price as an IBM, or compatible, desktop with the same features. Purchasing a desktop or a portable computer,

through government procurement methods discussed in the following section, have provided even lower prices on similar computers.

As indicated earlier, ruggedized portable computers are very expensive. For example, a portable ruggedized computer selected for deployment as a portable maintenance unit (PMU) for the MK 15 CIWS costs about $15,000 each (Wellteroth, 1993). The ruggedized computers selected for use in the Turbine Engine Diagnostician (TED) project costs $30,000 for color and $15,000 for monochrome (Helfman, 1993).

5. Government Procurement

The surest guarantee of quality and consistent competitive prices for a computer is to purchase through a government indefinite delivery indefinite quantity (IDIQ) contract. The government currently has IDIQ contracts for both desktop computers and portable computers (Desktop IV and Lapheld II, respectively). Table 4-2 lists computer features from both IDIQ contracts and the MAES minimum computer requirements. Basic details on each contract follow.

Feature	ZDS 0002AA Intermediate	GTSI 0002AA Intermediate	Lapheld II 0001AC	MAES Minimum Requirements
Microprocessor	486SX 25 MHz	486SX 25 MHz	486SL 25 MHz	386SX 20 MHz
RAM	4 MB 70ns	4 MB 70ns	4 MB	4 MB
Storage	115 MB IDE HD	170 MB IDE HD	120 MB IDE HD	60 MB HD
Monitor	14" SVGA	14" VGA	VGA (Mono)	VGA
Drives	3.5" & 5.25"	3.5" & 5.25"	3.5" Internal	3.5" or 5.25"
Mouse	PS/2 Logictech	2 button	Built-in Trackball	Mouse/Trackball
Open Slots	4 (2 drive bays)	4 (2 drive bays)	Type II PCMCIA	
Price	$1,799	$1,657	$1,100	

Table 4-2 Government Contract Computers Vs MAES Minimum Requirements

a. Desktop IV

Zenith Data Systems (ZDS) and Government Technology Services Incorporated (GTSI) offer desktop computer systems under the Desktop IV computer acquisition contract. The computers from both companies come with the latest versions of MS-DOS and Microsoft Windows software.

As illustrated in Table 4-2, the ZDS and GTSI desktop computers are nearly identical, except for the price and size of the hard drive. The ZDS computer is priced $142 higher than the GTSI and has a smaller hard drive. Both desktop computers exceed the minimum hardware requirements for the MAES.

Once GTSI accepts an equipment order, they are legally bound under contract to deliver the equipment within 14 days. A one year warranty is provided on all hardware purchased (Pacquin, 1993). Zenith delivers all orders within 21 days after accepting the order. They provide a three year warranty on all hardware items (Rickert, 1993). GTSI and Zenith will send all software updates and upgrades to the purchaser, at no charge, for three years after initial purchase.

Ordering information and a more complete description of the contracts can be received by calling the Navy's technical representatives in Norfolk, VA, at commercial (804) 445-2568 or DSN 565-2568.

b. Lapheld II

Another IDIQ contract is with INACOM. Lapheld II (N66032-92-D-0002) was awarded to be a source for laptop and notebook computers, including accessories. The contract offers 286, 386, and 486 computers with monochrome or color VGA displays. Pre-installed

software, which includes Microsoft Windows 3.11, Microsoft DOS 6.2, Watch Dog 7.03, and LapLink 4.0, is provided.

The portable computer specification of Lapheld II shown in Table 4-2, are functionally similar to its two desktop counterparts. The portable computer also exceeds the minimum hardware requirements of the MAES and costs $500 to $700 less than the desktops.

INACOM is required to furnish, at no extra charge, a three year warranty, which begins when the computer is delivered or fifteen calendar days after government acceptance, whichever occurs first.

According to the contract, INACOM must maintain the hardware by repairing any malfunctioning computer returned by mail or carried in to established repair centers by a government representative. INACOM has seven days from the time of receipt of the faulty computer unit to repair and return it to the government. This time includes return shipping, but does not include holidays or weekends. INACOM may be reached by telephone in CONUS at (800) 932-8235 and in Japan at 81-425-522-511, extension 9050.

To place an order on the contract, an original DD1155 and six copies must be forwarded to:

Technical Specifications and Support Branch
Code N811.2
NCTAMS LANT
9456 Fourth Avenue Suite 200
Norfolk, VA 23511-2199

There is a four percent acquisition and contracting fee required for delivery orders issued against the contract. It is applicable only to orders equal to or greater than $3,000. This fee can be made by using a separate or blanket funding document. NCTAMS LANT can be reached via DSN

565-1493 or fax 565-2103. Once the order is received by NCTAMS LANT, the expected delivery time is 45 days (Wienceck, 1994).

6. Expandability

Owning a computer that is obsolete in one year, or less, after the initial purchase is frustrating, to say the least. What is even more frustrating is owning a computer that can not be upgraded to keep it from becoming obsolete. On one hand, careful consideration would be given to what technology is available and the ability to upgrade or expand in the future. But in the case of MAES, if a decision is made to treat the computers as a piece of test equipment, then all that is needed is a computer that meets the minimum requirements. No upgrade or expandability may be needed.

For portable computers, two upgrade alternatives include installing miniature circuit cards using PCMCIA technology, or providing an interface, called a docking station, between the portable and a desktop computer. This allows the portable to use a desktop's peripheral devices. Both PCMCIA technology and docking stations are discussed in detail in Appendix C.

7. Warranties

An extensive literature review by the author found that all computer manufacturers provide, at no extra cost, a basic 12 month warranty (some offer 36 month warranties) for parts and labor. Most vendors offer extended warranties, available up to 36 months, at an extra charge. To qualify for the warranty, failed parts must be due to manufacturer defect. If the computer is damaged by dropping it or some other abuse, warranties would be void.

8. Accountability and Security

A main issue for the deployment of MAES is whether to consider it a personal computer or a piece of test equipment that is peculiar to the MK 92 Mod 2 FCS. If deployed as a personal computer it is likely it would be used for general purpose computing besides its intended use as a tool for troubleshooting the MK 92 Mod 2 FCS. This will provide additional wear and tear on the computer, subject it to possible virus infection and misuse as a computer game platform. Computer failure/breakage is likely to occur sooner than if it is considered and used only as test equipment. A dilemma which could also arise is the case where it is being used as a personal computer for some administrative function, and a technician needs to use it in troubleshooting. Depending on who is using it and the purpose, it may not be available.

Personal computers aboard Navy ships are accountable to the ship's ADP Officer, usually a collateral duty for a first class petty officer aboard Perry class frigates (Burns, 1994). The ADP Officer is normally responsible for the prevention of software piracy and viruses on the computer (Stemp, 1993). If handled as a personal computer, it becomes part of the accountable equipment which is normally inventoried once per year or upon change of command. The chief or leading petty officer of the work center assumes custody of the computer from the ADP Officer.

If MAES is deployed to the fleet with either a portable or desktop computer, the hardware could be implemented as a piece of test equipment. As such it would be designated solely for use with the MK 92 Mod 2 FCS. This avoids accountability problems (Franklin, 1993). NAVSEA should implement the desktop or portable as test equipment peculiar to the MK 92 FCS. Each unit would have a nomenclature reflecting its identity and unique serial number. NAVSEA already implements a desktop computer system in this manner aboard ships as part of

the MK 15 Close-In-Weapons-System's (CIWS) Integrated Diagnostic System (Haberzetle, 1993).

The Electronics Material Officer (EMO) has cognizance over all shipboard test equipment, and can manage the hardware and software by giving sub-custody to the technicians. As test equipment, the computer would be inventoried every three months (Burns, 1994). If the computer is lost the ship must replace it using its funds. This would provide better security awareness for the system.

Adequate security measures should be practiced for whatever hardware is selected. This would include such measures as preventing unauthorized personnel from using the computer and keeping the computer in a locked space when not in use. MAES processes only unclassified data, but is not authorized for public use. So it should be safeguarded with security measures commensurate with basic shipboard security doctrine. According to OPNAVINST 5510, the Navy's basic security doctrine, the ship is considered a controlled area, and adequate security for personal computers should be provided.

9. Fielding, Maintenance and Replacement

There are two alternatives for fielding a computer to the ships. The first is a computer furnished by NAVSEA or the Type Commander (TYCOM). The second alternative is that the ship must acquire its own computer or use an existing one.

If NAVSEA or the TYCOM furnishes a computer, it is more likely that the computer will be used as intended. In this case the computer would be implemented as a piece of test equipment. Stimpson claims that NAVSEA will unlikely provide the necessary funds to field the computers for deploying the MAES (Stimpson, 1994). The potential operational and

maintenance (O&M) dollar savings from implementation may induce the TYCOMS to furnish computers.

If the ship is required to furnish its own computer, inconsistencies between computer types will vary between ship-to-ship. The ship will likely account for the computer as normal ADP equipment, increasing the probability of the technicians occasionally losing the computer to an administrative need.

As previously discussed, it is the view of the NPS development team that MAES be initially implemented with a computer that is provided to each ship. The cost for these computers in fiscal year 1995 for 30 ships is expected to be less than $50,000. This expenditure will be offset by savings in the hundreds of thousands of dollars each year by deploying MAES.

There are two alternatives regarding work under a warranty. One alternative is for the ship to have the authority to return the defective computer directly to a contractor's repair facility. A second would be for a ship to send it back to either the TYCOM or configuration manager (NSWC PHD), who would in turn ship it to the warranty facility. If a computer proved defective, it would likely be repaired under warranty for at least the first year. If the computer was damaged by Navy personnel, ships may be able to obtain maintenance, for both desktop and portable computers, from Navy tenders and SIMA. A ship submits a form 2K (pronounced two kilo) to the Readiness Support Group (RSG) where a determination will be made whether a tender or SIMA will perform the maintenance.

A SIMA has the expertise to repair and upgrade most COTS desktop and portable computers that are IBM or compatible. For example, the SIMA in San Diego, CA, upgrades and repairs between 150 to 200 computers monthly and has a turnaround time of one to two weeks.

Their spare parts are largely COTS obtained from local businesses. (Elacio, 1994) The author anticipates that support is best for computers bought through the DoD IDIQ contracts.

Another issue facing the deployment of MAES on COTS computers is when one is damaged beyond repair (for either physical or dollar reasons). How will the computer be replaced? By the original activity that furnished it? Or should it be the responsibility of the ship itself to replace the computer? These are issues that must be resolved prior to fleet implementation. Having spoken to various activities, the development team leans toward the ship being responsible to replace damaged computers.

D. COMPARISON OF PORTABLE AND DESKTOP COMPUTERS

This section makes a comparison of portable and desktop computers as alternative platforms for deploying MAES. This is done by discussing the pros and cons of each computer.

1. Portable Computers

Appendix C contains the result of an extensive literature review on portable computer technology and provides more detail on issues surrounding the use of portable computers than what is discussed in this section. The reader is asked to refer to it for a more detailed discussion.

a. Pros

A portable computer's ability to be taken to the six possible work areas, previously depicted in Figure 4-1, is its most attractive feature. Technicians can take a portable computer with them wherever troubleshooting is necessary. In addition, the benefit of directly observing "How" and "Why" functions and viewing the graphics embedded in MAES provides considerable assistance not available when diagnostics are performed remotely through telephone communications. Such a platform allows all the features of MAES to be used. A portable

computer approach requires one less member of the troubleshooting team (i.e., the sailor that would have to sit by the desktop and have to relay all instructions).

Another important feature of using a portable computer is the ability to exploit SL CPU technology, often referred to as power down chips. These chips consume less power than older SX and DX models. The primary features of the SL chip includes: a CPU sleep cycle, CPU slow-speed option for idle times, and hard disk spin down cycle when not in use. These features are highly desirable in portable computers that must rely on battery power. One of the most useful features of the SL chip is that a technician can close the computer while troubleshooting and moving to a new location. If closed long enough the computer may turn itself off. Upon opening the computer (or restarting in the case where it turns itself off) the program would resume at the same point (i.e., screen) where it had left off.

Another advantage of portable computers is their small size. This allows them to be used just about anywhere on the ship.

b. Cons

The portable computer is not a panacea, and has inherent disadvantages for shipboard applications. These stem from its most desirable feature, portability. The primary disadvantage of a portable computer is its fragility. It is easy to drop it or knock it over. Other disadvantages include its small screen size, reliance on battery power, and minimal upgrade ability (although as discussed earlier this last item may not be a problem if fielded as a piece of test equipment).

The average screen display on most portable computers is 8.5 inches diagonally across. It may be difficult to view some text and graphics. Portable screens (except for active-matrix or dual scan) are also more difficult to view when in direct sunlight.

The "toy like" features of a portable computer attract a lot of attention. This attraction and its small size make the portable computer easily susceptible of being stolen. However, if adequate security procedures are followed, this risk can be significantly reduced.

Finally, a portable computer has a disadvantage of being more expensive to upgrade. PCMCIA technology allows portable computers approach many of the capabilities of their desktop counterparts, but at a greater expense.

2. Desktop Computers

The most logical place to mount a desktop computer for the MAES application is in the STIR equipment room. The room is used by the technicians as the centralized working space, tool storage area, soldering station, storage for technical publications, and administrative functions.

a. Pros

A desktop computer's primary advantage is that it can be securely mounted, thus reducing the risk of damage caused by falling or exposure to certain aspects of the shipboard environment.

The screen size normally measures 14 inches diagonally and is in color. The screen sharpness of a desktop monitor provides better viewing than a typical screen on a portable computer, though active-color matrix screens, available for portable computers, provide as sharp a picture as that of desktop monitors.

Another advantage of a desktop computer is that it can be upgraded at a lower cost than its counterpart, the portable computer. This is due primarily to the widespread use of

desktops and the high competition among vendors. However, this may not be a factor if the system is used only as test equipment and upgrades would not be necessary.

Repair and service for most desktop computers can be accomplished to some degree by Navy Data Systems Technicians (DS) aboard most ships, or at the Ship's Intermediate Maintenance Activity (SIMA). Repair capability for portable computers is not as well established as that of desktops.

b. Cons

Like the portable computer, the desktop computer does not provide a solution for all of the MAES deployment issues. The most undesirable feature of a desktop application is its inability to provide "How" and "Why" textual messages, and graphics embedded in MAES directly to the technician. These are primary assets of the program for the technician troubleshooting in one of the areas other than the STIR equipment room.

The lack of portability could be offset by two technicians, one operating MAES in the STIR equipment room, and the other technician in one of the other five areas. They would communicate by sound powered telephone circuits, with the technician at the computer reading each screen and inputting required responses. The "How" and "Why" screens could be read to the troubleshooting technicians. Doing so obviously degrades their usefulness. The benefits of displaying graphics to the technician would disappear unless the technician returns to the location of the desktop each time he needs a to view. This option is obviously impractical.

The fact that the troubleshooting process would require at least two people is also a major negative factor. Also, a technician using a desktop computer can not later resume the same

troubleshooting session in MAES if the computer is powered down, because SL technology is presently unavailable on desktop applications.

E. HARDWARE RECOMMENDATION

A UNISYS computer from the Desktop III contract, and portable Zeos Contenda computer, both containing identical versions of MAES, are being evaluated by technicians aboard the USS SIDES (FFG-14). The technicians will provide, by December 1994, valuable feedback on the issues previously discussed and may possibly provide new hardware issues to consider.

As previously discussed, the MAES is also being evaluated at the Fleet Training Center, San Diego, using an IBM ThinkPad 500C portable computer. Evaluation of the MAES has already been achieved on two other portable computers, a TI TravelMate 2000 and Toshiba Protégé.

From the initial sailor feedback, one of the most important characteristics of the MAES is its ability to provide the technician with Help functions by text, pictures, and diagrams. If the technician is unable to actually view the data provided by Help functions, the effectiveness of the MAES is greatly reduced. For this reason a portable computer is recommended for initial deployment to the first several ships. Further evaluation can be made during the initial evaluation period.

Computer technology experts agree that the hardware selected for deployment of an application should be readily available off-the-shelf. It should have more features than what is necessary to handle today's needs (Prerau, 1990). The minimum hardware required is insufficient for later versions of MAES that will integrate with a database and incorporate multimedia.

The following features, recommended for the portable computer selected for deploying the MAES, meet the minimum hardware requirements discussed in previous sections and listed in

Appendix C. They are pursuant with Prerau's philosophy of planning for future needs, are readily available today at competitive prices and minimize the overall cost.

- 80486SL\33Mhz CPU for optimum Windows, graphics, and database performance.

- 8 MB of RAM for optimum windows and database performance.

- 180 MB hard disk drive to allow for enhancements (especially for graphics).

- One Type II PCMCIA Slot to provide for future expansion of the hardware.

- One 3.5 inch floppy drive internally mounted for portability.

- Monochrome VGA active-matrix screen for sunlight readability.

- Internal trackball for portability.

- Samsonite carrying case from the Lapheld II contract, or equivalent, for durability amidst all steel and aluminum areas.

- NiMH battery with spare and charger for longer power and less environmental hazards.

  The next chapter discusses software implementation issues.

V. SOFTWARE IMPLEMENTATION ISSUES

A. OVERVIEW

This chapter addresses the subsidiary research question "What are the implementation issues for fielding MAES from a software developer's perspective?" This question is answered based on the author's experience with the development of the MAES and by following a methodology recommended by Prerau and other software development experts (Prerau, 1990, Shneiderman, 1992, and Beerel, 1993). The chapter is divided into six sections.

The first section discusses critical issues that involve the user interface to MAES. The second section discusses software issues that were encountered during the development of MAES. They include maintaining modularity, integrating the separate software modules, and packaging techniques for deployment. The following section discusses software deployment issues. It includes continued software support, intended functionality, maintainability, and reliability. The fourth section addresses key attributes the MAES must have before transferring it to the maintainers at NSWC. The fifth section discusses training the user and integrating the MAES aboard ship. The sixth and final section discusses program documentation.

B. USER INTERFACE ISSUES

This section discusses the issues that pertain to the user interface. Research by Stelzner and Williams indicates that the user interface of an expert system is critical to the success and implementation of the system (Stelzner and Williams, 1988). An expert system should have a friendly user interface that is well-defined (Prerau, 1990). Much of the difficulty users find while

interacting with an expert system stems directly from the poor design of the user interface (Shneiderman, 1992). In light of the author's experience with the development of MAES, a brief discussion is presented on what the author feels are six of the most important user interface issues. They are familiarity, user feedback, exiting the program, ease of use, explanation facility and consistency.

1. Familiarity

Learning anything new is usually a satisfying and rewarding experience. However, the author's experience as a navy instructor shows that many people during the learning process experience frustration and anxiety that comes from having to learn new concepts or complicated procedures. Those same people learned more quickly when the learning scenario included processes that were already familiar to them. For example, technicians will learn a weapon system quicker when they have previous experience with another weapon system.

The user interface design determines how well the user interacts with the application. When the user is familiar with the methods of interaction (e.g., using a mouse), it will be easier for him to accept the system. This means that the user should be able to easily recognize what is being presented by the program. To accomplish that, screen layout and program features should be uniform throughout the program. For example, the user interface for MAES is a Windows compatible interface. An unfamiliarity with that interface may be intimidating to the user and result in the user not accepting the program. Training should alleviate any difficulty the user may have navigating through Windows. The MAES Prototype 1.0 User's Manual (Appendix B) includes a brief tutorial on the use of Windows.

2. User Feedback

Users often find it difficult to interact with expert systems because they may not understand what the program is doing (Brown, 1989). A user expects something to happen when a button on the screen is clicked or the enter key on the keyboard is pressed. Therefore, for every operator action there should be some system feedback. A message telling the user what the system is doing may be all that is necessary (Waterman, 1986). The following example is given to show the results of a system with poor feedback.

The first operators of the American Airlines computer reservation system, SABRE, caused the system to fail because they overwhelmed the system with duplicate information (Sprague, 1993). Operators entered transactions by typing the data on the keyboard and then pressing the enter key after each transaction. However, no feedback to the operators that their transactions had been accepted (or rejected) by the system was given. As a result, operators would continuously press the enter key until the system finally responded with a new cursor position. Unknowingly the operators entered dozens of duplicate reservations which inundated the system in a short time. To correct the problem developers quickly modified the program with a feedback feature that informed the user when the data had been accepted (or rejected) by the system.

In MAES additional information is provided through the use of window type messages and audible beeps. A message window appears whenever the user is about to make an irreversible decision. These decisions include switching between the FC1, FC2, FC4&5 and Calibration modules or when exiting the program. An audible beep occurs when these windows appear, alerting the user that a major decision is to be made.

3. Exiting the Program

An easy way to exit the program should be available at all times to the user. It is the author's experience during development of MAES that the user will exit the program by turning off the computer if an apparent method to exit is not available. Appendix B describes the pitfalls (i.e., wasting disk storage) of exiting Windows' programs in this manner.

A technician may exit MAES at any point in the program by double clicking with a mouse on the control box in the upper left corner of each window. In addition, buttons have been placed in portions of the Calibration Module that enable technicians to escape from their current display and go back to a previous location within the module or allow them to exit the module altogether.

4. Ease of Use

Another important software issue to consider is ease of use (Prerau, 1990). Users must find the expert system and its features easy to use. The MAES must be easy for fire control technicians to operate, or they very well may resort to previous methods of troubleshooting. On visits to fleet units, technicians aboard the USS SIDES and at the MK 92 FCS Maintenance School found MAES easy to use. They were able to familiarize themselves and navigate through the program in a matter of minutes.

Any questions that are to be asked of users should be clear and concise. A computer's man-machine interface has little conversational capabilities. Recommendations made by MAES are easy to accomplish and are within the user's ability to perform. Both "How" and "Why" explanations are included with any recommendation. These features are discussed in the following section.

5. Explanation Facility

An effective user interface must be able to provide the user with an explanation of the expert system's reasoning or deductions (Bielawski, 1990). As discussed in Chapter II, expert systems should provide the user with an explanation to how or why a particular conclusion was reached (Waterman, 1986). For example, technicians may wish to know why they are asked to perform a certain voltage measurement. MAES provides explanations to such questions through "Why" and "How" features. They are included in most Calibration display screens and some Performance display screens, when the engineers believed they would be useful. They also serve as a training aid for less experienced technicians.

6. Consistency

When expert systems are being developed by more than one programmer, it is important to establish a standard "look and feel" to the user interface. Users expect a certain amount of consistency in what they see. Buttons used for the same functionality (e.g., "Yes" or "No" buttons) should be consistently labeled and located on all displays. A common mistake found in the prototype Performance Module was the use of the labels *Exit, Escape* and *Return* interchangeably. This mistake has been corrected in the current version.

Consistency is the hardest design process for software developers to follow, especially when there are multiple programmers. When consistency is implemented, it reduces training and maintenance costs (Brown, 1989). It is equally important for program maintainability and is further discussed in the following section.

C. SOFTWARE DEVELOPMENT ISSUES

There are several software development issues that impact the implementation of MAES. The primary ones are discussed in this section and include maintaining modularity, integrating the separate modules, and packaging an installation version.

1. Maintaining Modularity

Maintaining modularity allows a program developed by different programmers to be easily integrated. In addition, a modular program is easier to read, understand and maintain. Structurally, components of the expert system should be very similar to the components of the expert knowledge. (Prerau, 1990)

A module is a component that is designed to be integrated into a system. MAES has two modules, Performance and Calibration. The Performance Module is comprised of coding that is particular only to the Performance aspect of DSOT. It is made up of three Adept applications, called FC1.adp, FC2.adp, and FC4&5.adp, respectively. Likewise, Calibration Module is coding that is peculiar to Calibration and is contained in one Adept file, called Calibrat.adp.

These four application files comprise MAES Prototype 1.0. Figure 5-1 illustrates how the individual applications are linked to a fifth file to form MAES Prototype 1.0. The fifth application file, MAES_1.adp, is needed to allow the user to select one of the other applications. Tying the four application files to the MAES_1.adp gives the impression to the user that there is only one program file. At the same time, this modular approach promotes maintainability.
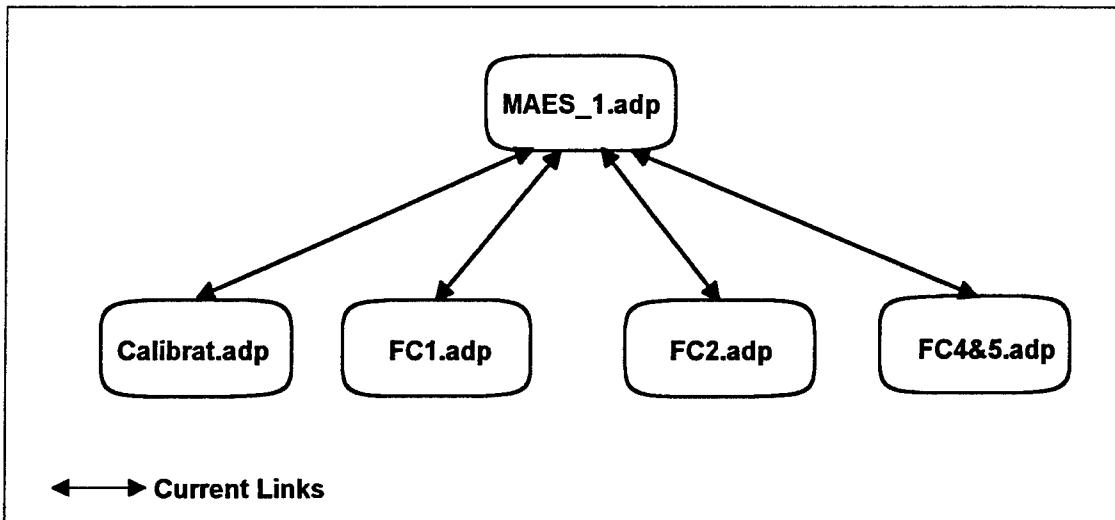
Figure 5-1 MAES Prototype 1.0 Adept Applications

2. Integrating the Modules

As previously stated, modules are component files that make up an integrated system. The integration of the Performance and Calibration Modules in one large application was originally planned (Lewis, 1993 and Geick, 1994). However, a decision was made not to integrate MAES Prototype 1.0 one application for two reasons: first, use of global variables may cause the system to provide erroneous results or even crash and secondly, inconsistencies destroy the modules background display screens makes a clean integration impossible. A discussion on each of these two issues follows.

a. Use of Global Variables

Variables in Adept are declared globally or locally. Global variables are shared throughout the entire application and can be called from anywhere in the program. Local variables are only recognized and used in the procedure in which they are declared.

Each of the five applications that form MAES Prototype 1.0 uses global variables. Since the same name of some global variables were used in different procedures, potentially erroneous information would have resulted if the five applications are integrated into one large

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application. The following is an example of how the system could give a technician erroneous information.

In the process of using MAES to isolate a fault in the MK 92 FCS, a technician discovers that target clutter is not present in a particular measurement relating to the STIR portion of the system. The technician inputs this condition into MAES and a global variable in the Calibration Module called "Target_Clutter" is assigned the boolean value of "false". The technician later enters into the CAS portion of the system. The CAS component is very similar to STIR and also has a global variable named "Target_Clutter". The MAES already assumes there is no target clutter in the CAS portion of the system. But target clutter for CAS may very well be present (it would be represented by a "True" value). The technician may not, therefore, be given the opportunity to enter a valid response. In this situation we have target clutter but the program believes it to be absent (a "false" value) and takes the technician down the wrong path.

This can be overcome in two ways: first, declare variables locally, or secondly, reset variables throughout the program (Himes, 1991). Both ways require that each variable be traced through the program to see how it is used in each procedure. Once this process is accomplished variables can be declared as local variables or reset at the beginning of each procedure, depending on the methods used. Using the ResetVariables function in Adept requires extensive program modification. Both methods are described in detail in the Adept User's Manual.

The overuse of global variables is planned to be corrected in future versions of MAES. Until the corrections are made, integration into one large application should be avoided.

b. *Programming Inconsistencies*

Adept supports one background screen that is common throughout the application. Performance and Calibration have different background screens, thus making integrating difficult. The production version is scheduled for completion in December 1994, and will eliminate the inconsistencies in the background displays of the two modules.

3. Packaging MAES

The MAES Prototype 1.0, consisting of five individual files, is over 12 MB. This presents a problem on how to package or distribute the program. The problem occurs when trying to save the application to floppy disks for distribution and installation. To alleviate this problem, one of three alternatives may be used to package MAES.

a. *Using Microsoft Utilities*

One commonly used method of packaging files that are larger than the capacity of a single floppy disk is through the BACKUP and RESTORE features of MS-DOS™ 6.2. Using the BACKUP feature, the current version of MAES can be compressed onto three 3.5 inch HD floppy disks. The files can be installed on a different computer using the RESTORE function. This method requires the use of DOS BACKUP and RESTORE of DOS 6.2.

b. *Using a DOS Batch File*

An older method of packaging a program for distribution is through the use of zip and unzip utilities. Older versions of these utilities are public domain and can be distributed freely. The files are individually compressed using the zip utility and copied onto floppy disks. The compression usually occupies only one-half the disk space that the uncompressed files use.

This process includes the use of a DOS batch file to unzip the files onto another computer's hard disk. The batch file contains the unzip command, the names of the zipped files, and the directory in which to place the unzipped files. Transferring the program to the destination computer is done at the DOS prompt by typing the name of a batch file that contains the unzip instructions. This method requires a user to be familiar with entering DOS commands.

c. Using Installation Software

The two previously discussed methods leave a user with the task of creating a group icon and a program icon for use in Windows. This may be a confusing process for novice users. Using installation software creates both a Windows group and icon for the user. This method is the easiest of the three to use and is initiated through Windows.

The preferred packaging method for MAES Prototype 1.0 distribution is through the use of such a professional installation tool, INSTALIT For Windows (IFW) 4.5[1] . The tool requires the use of custom script files for the MAES application to package it onto two ready-to-run installation disks. Appendix E contains the script files developed as part of this thesis and used in conjunction with IFW 4.5 to produce an installation package for the MAES Prototype 1.0.

D.   SOFTWARE DEPLOYMENT ISSUES

Figure 5-2 depicts MAES and its associated software. It includes Microsoft DOS™ 6.2, Microsoft Windows™ 3.1, Microsoft Access™ 1.1, and the SoftSell Adept™ 2.2 runtime shell. The user must interface through three levels of software (DOS, Windows, and Adept) to operate MAES. DOS is transparent to the user, but is included here for completeness. Earlier attempts to

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[1]   INSTALIT for Windows is a professional, general purpose script driven installation program for Microsoft Windows and is distributed by HPI of Huntsville, AL.

directly interface Adept with Access were unsuccessful (Talley, 1994). As a result, the database portion of the MAES Prototype 1.0 must be accessed directly from Windows. It is hoped that later versions of Adept will allow the user to access the database directly from MAES. Normal use of DOS, Windows, and Access are permitted should a user desire.

Before MAES can be deployed, it must have continued software support, intended functionality, and reliability. Each of these topics is briefly discussed in the following sections.
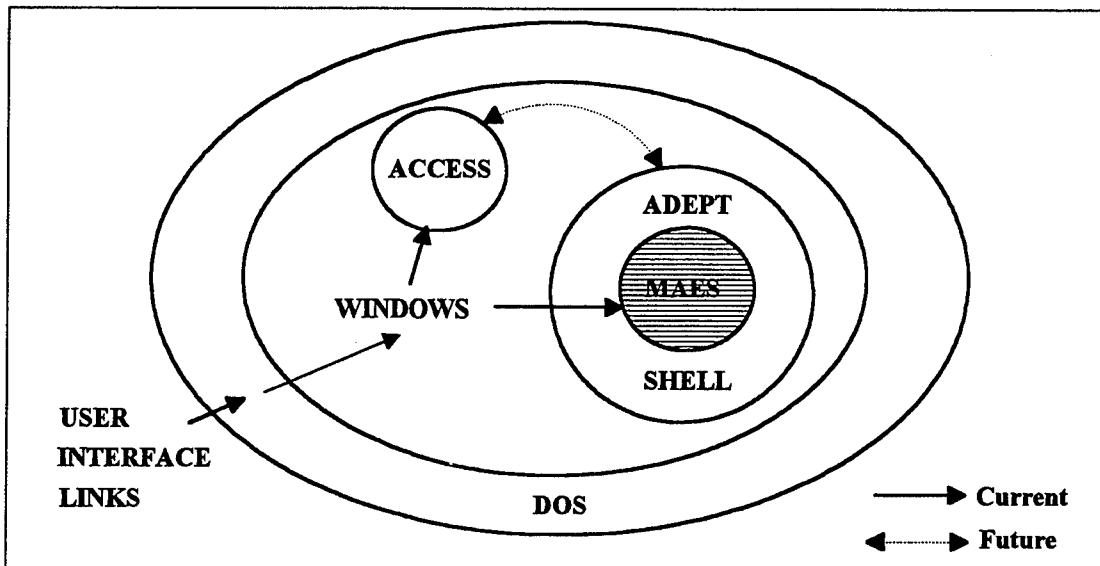
Figure 5-2 MAES Prototype 1.0 and Supporting Software Shells

1. Continued Software Support

Without continual updates and enhancements a software program will become out-of-date. If MAES is going to be successfully deployed and used, consideration must be given that the MAES knowledge base and associated software, depicted in Figure 5-2, receive continued support.

a. Continued MAES Knowledge Base Development/Maintenance

There are four issues concerning continued knowledge base development and maintenance that need to be considered. To date, only two thirds of the planned functionality

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(Performance and Calibration Modules) has been implemented. The full implementation of MAES includes a third module, RF Power Checks, which is scheduled to be developed in the first two quarters of fiscal year 1995.

A near term issue concerns the funding for the current domain expert. This expert would be the key source of knowledge for developing this module. Presently, a UNISYS support contract that includes the service of the expert will expire at the end of fiscal year 1994 (Seto, 1994). This contract may not be funded/renewed for next year. An alternative would be to use the other domain expert at NSWC. Funding has been requested of NAVSEA, part of which would be to continue an expert's knowledge documentation of RF Power Checks. RF Power Checks contributes approximately one third of the present system's knowledge and therefore one third of the potential benefits -- NFE savings, MTTR savings, and improved readiness (Powell, 1993). It is strongly recommended that this module be implemented.

The next issue is that the knowledge base has the potential to become outdated. This is especially true in expert systems designed for diagnostic purposes on Navy fire control systems. Through their system life these systems receive circuit modifications called ordinance alterations (ORDALTs). If the MK 92 Mod 2 FCS receives an ORDALT, then MAES should be modified accordingly to reflect the changes created by an ORDALT.

The third reason for continued knowledge base support is the possibility of errors and inaccuracies in the current knowledge base. These errors and inaccuracies can come from various sources. The domain expert may have made a mistake while formulating the knowledge or transferring it into a paper document. Errors also stem from programmers improperly implementing the knowledge document.

The final reason to continue life cycle support would be to add enhancements or expand the knowledge to other aspects of the system.

b. Symbologic Adept

The issue to consider here is the likelihood that the vendor of the expert system tool will still be in business upgrading and maintaining their product during the life cycle of MAES. Prerau claims that a tool with a broad customer base is likely to be maintained by the original company, or if taken over by another company, maintained by them (Prerau, 1990). This seems to be the case with the expert system tool selected to develop MAES.

As previously discussed in Chapter III, the expert system tool selected to develop MAES was Symbologic Adept™ 2.1. The Symbologic Corporation sold Adept to SoftSell in October 1993. SoftSell will have exclusive rights to the software by 1996. Both SoftSell and Symbologic are located in Redmond, Washington.

The software is continually being updated by SoftSell. Adept 2.2, released in January 1994, adds additional graphic interface capability with TIFF, PCX, BMP, GIF, DIB, TARGA, WPG, and WMF files, and allows bitmaps to be resized.

The upgrades to Adept are important so future enhancements to MAES can be accomplished. For example, Adept 2.2 has limited support for multimedia use. In addition, there is limited integration with database management systems, such as Microsoft Access™ 1.1. Future versions are planned that will meet multimedia standards and provide integration with COTS databases.

Adept 3.0, projected for release in mid 1995, will be compatible with earlier versions, and provide an electronic documentation feature, a multi-background capability, and the ability to return to previous screens without additional programming.

SoftSell has a broad customer base with over 500 hundred copies of Adept 2.1 (Klock, 1993). There are other government agencies that presently use Adept for expert system development. They include the U.S. Army Research Lab and Knowledge Engineering Group developing a diagnostic application for the turbine engine in the M1 Abrams Tank and the National Park Service which is developing the Yellowstone Fishing Advisor to be used by visitors at Yellowstone National Park. Howell Industries is also using Adept for development of a diagnostic system for the LM2500 gas turbine engines used by the U.S. Army.

c. *Microsoft DOS, Windows, and Access*

The issue of continued software support also applies to Microsoft products. As previously discussed, MAES requires the use of DOS and Windows. Access provides the database support for MAES. These products must be upgraded and maintained during the life cycle of MAES so the developers at NPS can make future enhancements (such as multimedia).

The Microsoft Corporation, which has over 10,000 employees and gross annual software sales of $3.75 billion, has a reputation of quality products and user support. There is little question that Microsoft will continue to support its products.

2. Intended Functionality

Buchanan and Shorliffe discuss a method of approaching the proper diagnostic level, either schematic or functional. They assert this method is a critical issue with regards to the functionality of an expert system designed for diagnosing electronic equipment (Buchanan, 1984).

The schematic level directs a user to the individual components of circuit cards. It requires that the user have a thorough knowledge of the actual electronic circuitry. The functional level applies diagnostic concepts and focuses at the card replacement level.

The selection of a broad functionality or detailed schematic level approach must be done early in the requirements phase and then implemented into the design of the expert system. The MAES takes the user to the functional level, where even the most junior technician should be able to understand the questions and instructions presented by the program.

3. Reliability

Reliability of an expert system can be defined as the likelihood of the program operating without fault or failure for a specified period (Prerau, 1990). In other words, reliability is the probability of no failures occurring during runtime or operation of the system.

In order to successfully deploy an expert system, it must be considered reliable. There are at least two interpretations of reliability. First, as with any software program, execution of the program needs to be flawless. That is, it should not lock-up, return a user to some incorrect part of the program, or exit the program unexpectedly. A second interpretation is the accuracy/correctness of the knowledge embedded in the system. If the knowledge or instructions to the user are incorrect the program will be judged unreliable.

Reliability of MAES is essential for its success. The ultimate test for the system is it must gain the confidence of the ship's technicians to be considered reliable.

E.   TRANSFER OF MAES TO NSWC

NSWC Port Hueneme Division will become the configuration manager for MAES. According to Prerau, the technology transfer of an expert system is best accomplished if the

knowledge and its associated coding is concise, understandable, and is well documented. The reader should recall that the coding, done procedurally, is discussed in an earlier chapter. The discussion about documentation for MAES is in a later section. This section provides a list of key attributes for expert systems, the role of NPS, and the role of NSWC.

Prerau provides a list of key attributes of an expert system, which make it easier to deploy, operate, and maintain (Prerau, 1990). They are:

- The program data and control flow is clear.

- The program is divided into several well-defined modules.

- The program is written using a uniform programming style.

- Uniform naming conventions are used throughout the program.

- Intermodule data access is standardized.

- The knowledge documentation is well written and clearly specifies the domain knowledge.

- The program documentation is well written and complete.

- The knowledge is implemented using paradigms that are relatively easy to maintain.

These attributes are being accomplished by the NPS project team, and should continue to be conducted during the entire life cycle of MAES by the maintainers at NSWC.

1. Role of the Naval Postgraduate School

The role of NPS has been to develop the MAES software, evaluate implementation alternatives, and prepare for the transfer of configurations management to NSWC. In developing the MAES software modules the development team followed the knowledge diagnostic trees presented in the domain expert's knowledge document. The graphical representation of the data

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and control flow is easily seen when the knowledge diagnostic trees and the program's procedures are viewed simultaneously. This should allow for ease of maintenance of the program procedures.

A weakness of modular programming with more than one programmer or a team of programmers is the likelihood of not following uniform programming styles. Another problem is maintaining uniform naming conventions. These two attributes are weaknesses in the MAES Prototype 1.0, but are addressed in the final production version by restructuring the Performance Module. This effort has already been initiated and is scheduled for completion in December 1994.

Another objective for the NPS development team is to consolidate and turn over to NSWC the documentation for the life cycle support. The knowledge document is continually evolving. It is a well written and easy to read document. It is being digitized to enhance the ease of readability and to provide a source of future maintenance. Documentation is further discussed in Section G of this chapter.

From the outset, the NPS project team planned to transfer MAES to NSWC in Port Hueneme for deployment and maintenance. The transfer of system knowledge has been gradually underway by providing the engineers at NSWC with updated versions of Adept, prototype versions of MAES, and documentation for review. Periodic face-to-face meetings between NSWC and NPS personnel have occurred throughout the development.

As part of the transfer process, all program documentation should be provided to, and understood by, the engineers at NSWC. As program documentation is developed, copies are given to, and discussed with, NSWC. The transfer of configuration management of MAES to NSWC should include all program documentation. Section G of this chapter describes each of the documents.

2. Role of the Naval Surface Warfare Center

As previously mentioned, NSWC will become the system configuration manager. They should establish resources to coordinate for one or more skilled personnel to install and support the appropriate hardware and software aboard ships. They also need to be prepared to accept the project deliverables and conduct long-term maintenance of MAES. NSWC should also provide technical support and training to the Fleet Training Centers (FTCs).

Before a complete transfer of MAES from NPS, engineers at NSWC should be very familiar with the program by fully understanding the program's structure, use of variables, objects, and terminology. This process has already begun. The NSWC project engineer is familiar with the Adept software and has helped in adding graphical capabilities to the prototype.

As previously discussed, a problem exists with terminology used in the MAES Prototype 1.0. It is sometimes inconsistent within the prototype Performance Module, and between the Performance and Calibration Modules. The production version of software will eliminate these inconsistencies before the transfer of MAES to NSWC.

F. USER TRAINING AND INTEGRATION

The issues pertaining to training the user and integrating MAES aboard ship are discussed in this section.

1. Training the User

According to Beerel, user training is one of the most significant reasons given for successful system implementation. She further adds that the training should include a description of the expert system and explanations why it is being implemented. On-line training should also be available to reinforce the formal training. (Beerel, 1993)

Training should be conducted by NAVSEA and FTC personnel at the time MAES is delivered to ships. In demonstrations aboard the USS SIDES and at FTC San Diego, one-half day of training was all that was needed to get technicians comfortable with using MAES.

Training should parallel the user's manual, discussed in the next section. It includes how to use windows, how to install the program, how to start and exit the program, how to navigate through the program, how to access program help, and how to receive program support. Hardware issues, discussed in Chapter IV, should also be covered. Training should also reinforce well established troubleshooting procedures that MAES frequently directs to be done.

Another source of training on basic use and care of personal computers and how to use Microsoft Windows™ is available through the Automated Data Processing (ADP) Fleet Support Centers located in Norfolk, VA, and San Diego, CA (Buckley, 1994).

2. Integration Aboard Ship

The MAES Prototype 1.0 should integrate into the technicians working environment without great difficulty. A reason why technicians may find it difficult to fully accept an expert system is because they may expect too much from it (Prerau, 1990). Users need to be aware that MAES does not address every potential problem that may occur in the MK 92 Mod 2 FCS. MAES will lead the user to a high number of problems that are detected while running DSOT and resolve them. But, technicians must realize that MAES has limitations and, like an expert, can make mistakes.

On the other hand, if MAES proves to be a valuable asset to technicians, one concern is that they may become too dependent upon it. Complete troubleshooting reliance on the system

should be avoided. A realistic expectation should be to view the system as an aid to the troubleshooting process, not the solution.

MAES closely resembles troubleshooting block diagrams the technicians already use. However, the expert system provides considerably more detailed knowledge than the publications and includes an automated approach to locate casualties. Where technical manuals generally isolate a problem to an ambiguity group of several cards, MAES, in most cases, isolates down to a specific card.

Early indications are that the integration of MAES into the existing culture aboard ship should not be difficult. The technicians, combat systems officer, and commanding officer aboard the USS SIDES eagerly accepted the MAES and see little, if any, integration problems aboard their ship. NAVSEA and MOTU-5 technical representatives (Seto, 1994 and Ursich, 1994) and the chief of staff for DESRON ONE (Goldberg, 1994) agree that the MAES should integrate well into the shipboard environment.

G. DOCUMENTATION

Beerel agrees that developing documentation for an expert system is just as crucial as any other software. In addition, she claims that traditional software documentation is too labor intensive, costly, usually inaccurate, often redundant, and out-of-date before publishing. She advocates automating software documentation simultaneously with configuration management. (Beerel, 1993)

The documentation for MAES includes the knowledge diagnostic trees, printouts of coded procedures, detailed text identifying the coded procedures, validation and verification forms, a user's manual, and copies of all thesis written by NPS students on the MAES project. The

collection of these documents comprise the MAES Maintenance Manual and are depicted in Figure 5-3.

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│  ┌──────────────┐    ┌──────────────┐    ┌──────────────┐        │
│  │  KNOWLEDGE   │    │  PROCEDURE   │    │  PROCEDURE   │        │
│  │  DIAGNOSTIC  │    │  DIAGRAMS    │    │  DESCRIPTIONS│        │
│  │  TREES       │    │              │    │              │        │
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│              ╲              │              ╱                       │
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│              ┌──────────────────────────┐                         │
│              │        MAES              │                         │
│              │    MAINTENANCE           │                         │
│              │       MANUAL             │                         │
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│  ┌──────────────┐    ┌──────────────┐    ┌──────────────┐        │
│  │  TESTING,    │    │  SUPPORTING  │    │    MAES      │        │
│  │  VALIDATION, &│   │  SOFTWARE    │    │   USER'S     │        │
│  │  VERIFICATION│    │  MANUALS     │    │   MANUAL     │        │
│  │  FORMS       │    │              │    │              │        │
│  └──────────────┘    └──────────────┘    └──────────────┘        │
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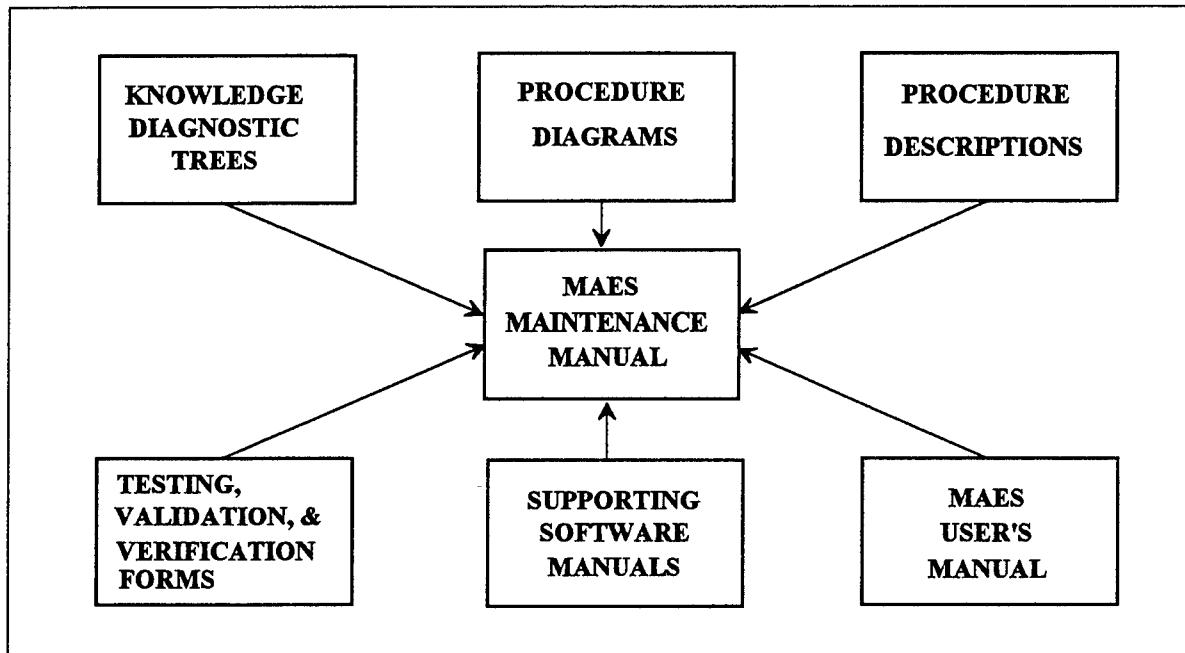
Figure 5-3 MAES Documentation

1. Knowledge Diagnostic Trees

The knowledge diagnostic trees were discussed in Chapter III and illustrated in Figure 3-4. These trees are presently contained in two volumes, Performance and Calibration. They are currently in the knowledge engineer's handwriting, and are in the process of being digitized. (A third volume for Power Checks will be completed in 1995.) These trees will be critical for reviewing any knowledge problems in MAES or for expansion of knowledge in these modules.

2. Procedure Diagrams and Text

A sample procedure diagram was also discussed in Chapter III and is depicted in Figure 3-5. Detailed text explaining the procedures in the prototype Performance Module is contained in two master's thesis (Lewis, 1993 and C. Smith, 1993). Procedure diagrams and detailed text representing the knowledge diagnostic trees for the Calibration Module are also contained in a

master's thesis (Geick, 1994). Revision and redesign of the Performance Module is documented in a master's thesis (L. Smith, 1994). These documents will be key references for software maintenance on MAES.

3. Validation and Verification Documents

Validation pertains to whether or not the system does what it is meant to do, given a certain level of accuracy. Verification pertains to whether or not the system is implemented to specification. In other words, validation determines if the correct system is built, and verification determines if the system is built correctly. These documents record errors found during testing. Their purpose is twofold. They serve as a historical document for the errors discovered over the life cycle of MAES. The other purpose is to guide the maintainers to the area of the program where the error or errors were discovered. Documentation supporting the validation and verification of the knowledge contained in MAES is discussed in a master's thesis by Tutt and Dills. (Tutt and Dills, 1994)

4. MAES User's Manual

The Rand National Defense Research Institute recommends that a user's manual for an expert system should include user help, how to browse through the knowledge base, a description of error messages, how to exit the program, and a way for the user to make comments or suggestions to the developer (Kamey, 1989). Rand's method formed the basis for MAES Prototype 1.0 User's Manual. This manual is contained in Appendix B.

The manual begins by introducing the user to the development of MAES, followed by a brief discussion on operating in a windows environment. The windows section is included for users that may be unfamiliar with Microsoft Windows™.

The user is provided detailed instructions on how to install MAES on a computer. This section of the manual guides the user through the installation process. Display screens encountered during installation and detailed step-by-step instructions are provided.

The manual describes the various ways to start and exit the program, followed by a section describing how to use MAES. This section includes: screen layout, input methods, and help information. Other help information with regards to circuit card replacement is also provided. The information presented includes generic card replacement procedures and rules to follow after card replacement. These procedures are also available on-line to the user as depicted in Figure 7-1 of the manual.

The manual includes a step-by-step example of a casualty in the Calibration portion of DSOT. These steps lead the user through a series a display screens, similar to the ones the user will likely encounter during most casualties, which ends with a recommended part replacement. The features of the system are pointed out to the users.

The manual also provides the user with information on how to obtain technical assistance from NAVSEA, NPS, and UNISYS. This information is also included on-line as depicted in Figure 7-1 of the manual.

5. MAES Maintenance Manual

The MAES Maintenance Manual, depicted in Figure 5-3, is a compilation of the documents discussed in this section. In addition the manual includes the supporting software user's manuals for Microsoft Windows 3.1, Microsoft DOS 6.2, Microsoft Access 1.1, and Adept 2.2.

The next chapter provides a summary of conclusions and recommendations.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. OVERVIEW

Implementation issues addressed in this thesis apply to the MAES life cycle phase between development and the deployment of the production version. It answers all of the research questions which are restated in this chapter. This chapter summarizes conclusions about those implementation issues, particularly hardware and software. The chapter also provides recommendations for fielding MAES and follow on research.

B. SUMMARY OF CONCLUSIONS

This thesis answers one primary research question and four subsidiary research questions. This section is divided into five sections, each one corresponding to a question. The primary question is answered in conjunction with the first two subsidiary questions.

1. Primary Research Question

The primary research question for this thesis is *"What are the production version implementation issues for diagnostic expert systems"?* The implementation issues deal with the system's hardware and software, training, and life cycle configuration management and support. The system may be implemented on either portable or desktop computers. Execution of a QMB proposal will provide the opportunity for evaluating these alternatives and receiving shipboard experience and feedback. While this initial

research on the issue recommends using a portable computer, more detailed information will be available from the QMB.

The software must be user friendly and reliable. It should correctly solve the problems it covers. The production software needs to be maintainable. Structured methodologies, consistency, and the required maintenance documentation should be implemented.

One should not assume that training will be unnecessary just because the delivered program is Window's based and only requires "point and click" inputs. A one-half to one day training course should be provided. A user's manual should be available. NSWC personnel and FTC personnel should conduct the training.

NSWC will eventually become the configuration manager for the system. As such it will assume maintenance responsibilities for the software. As discussed earlier, maintenance of the hardware would become the responsibility of the user organization, augmented initially by any warranty.

Hardware issues are addressed in detail in Chapter IV and supported in Appendix C. It is concluded that the hardware must:

- Efficiently and effectively operate MAES and its supporting software.
- Enable the MAES to maintain portability.
- Operate in a shipboard environment.
- Be commercial of the shelf (COTS).
- Be affordable and readily available.

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- Allow for expansion.

- Be maintainable.

2. Research Question #2

This section answers the research question *"What hardware is best suited for implementing the MAES aboard ship"?* The hardware issues associated with this question are addressed in Chapter IV. Appendix C supports the hardware decision by presenting current notebook computer technology.

The initial recommendation is that a portable computer is more desirable than a desktop computer because it enables MAES to maintain its intended portability. Portable computers could be procured readily through the IDIQ LAPHELD II contract. A specific notebook computer that meets the MAES requirements is identified by CLIN 001AC. It provides the functionality needed to deploy MAES aboard ship. Chapter IV describes the contract and lists the notebook's hardware features in Table 4-2. As previously mentioned, the proposed QMB assessment will provide an excellent opportunity for a much broader analysis on the best shipboard platform.

3. Question #3

The next research question is *"What are the implementation issues for deploying the Maintenance Advisor Expert System from a software developer's perspective"?* The software issues are discussed in greater detail in Chapter V. The deployment issues the software developer faces are:

- Providing a friendly user interface.

- Maintaining modularity.

- Integrating the modules.

- Packaging the program.

- Ensuring continued software support.

- Developing a program that is maintainable and reliable.

- Ensuring intended functionality is achieved.

- Transferring the program to the configuration manager.

- Training the users and integrating the program into their environment.

- Developing complete program documentation.

4. Research Question #4

This section answers the research question *"What are the required procedures for implementing new diagnostic software and associated hardware to the fleet"?* There are no recorded processes contained in Navy instructions that detail the procedures for implementing diagnostic software and its hardware to the fleet. Expert system technology is relatively new to the Navy. The use of diagnostic expert systems is not widespread enough to require policy makers to develop required procedures.

Until a policy is established, the type commanders (TYCOMs) can grant the authority to implement MAES aboard their ships. The project manager for the MK 92 FCS at NAVSEA must obtain approval from the TYCOMs by written authority to implement the production version of MAES to the fleet. The written authority will be a

general service message distributed to all commands involved with the MK 92 Mod 2 FCS. (Stimpson, 1994)

5. Research Question #5

This section answers the final research question *"What is the feasibility of using MAES as a training aid"?* Chapter II discussed how expert systems can be used as an instructional tool (training). MAES does not incorporate any mechanism to instruct the user when he has wrongly applied his own knowledge, but by its very nature as an expert system, can train the personnel who use it. Since the MAES already contains the knowledge of an expert and has the ability to explain reasoning processes, it is feasible to serve as a training aid to the technicians aboard ship.

C. RECOMMENDATIONS

This section provides recommendations for completing the development of MAES, fielding MAES, soliciting user feedback, and follow on research.

1. Completing Development

It is recommended that the development of MAES be completed. This recommendation is based on three reasons: cost savings, invaluable program development experience that is transferable to other systems, and the help it provides sailors. First, Powell's economic analysis reported significant cost savings can be realized over the life of the system. He also reported that operational readiness can be improved by 10 percent. (Powell, 1993) Secondly, valuable lessons can be learned by completing and fielding MAES. This experience can be applied in the development of expert systems for other

maintenance intensive weapon systems. Finally, the sailors need the type of assistance that MAES can provide. As previously stated in Chapter V, an expert system such as MAES is needed and highly desirable as noted by DESRON, NAVSEA, MOTU-5, and the ship

2. Fielding Recommendations

The Naval Postgraduate School has submitted a Quality Management Board (QMB) assessment proposal to NAVSEA for the initial fielding of MAES during fiscal year 1995. The proposal includes fielding seven systems to COMNAVSURFPAC ships. The recommended deployment would be: (Seto, 1994)

- Two of the four ships listed in Appendix A with home ports in Yokosuka, Japan.
- The USS CROMMELIN (FFG-37) in Pearl Harbor, HI.
- The USS SIDES (FFG-14) and three additional ships located in San Diego, CA.

The system would include a portable computer that is pre-loaded with MAES and supporting software. The systems will be delivered to each of the ships by a representative from NSWC PHD. The representative will train the users and ensure that the system is functioning properly. Because this is a new approach to doing maintenance the option of sending the software and hardware to the ship by mail without training is considered inappropriate.

The option of giving the ship the software without the hardware is also an undesirable alternative. The ship must be supplied with both the software and hardware dedicated for troubleshooting. Ships should not be expected to purchase the initial

computer dedicated to this one task. MAES should be introduced as a system which includes the hardware and software necessary for its employment.

The original strategy included fielding three additional systems to each of the three COMNAVSURFPAC Mobile Ordinance Technical Units (MOTUs) located in Yokosuka, Pearl Harbor, and San Diego. Because of budget constraints and downsizing efforts, the Navy is consolidating MOTUs and NAVSEA technical units into a newly formed organization called Fleet Technical Support Center (FTSC). One system will be sent to each of the FTSCs.

3. Soliciting User's Feedback

This thesis developed a MAES Prototype 1.0 User's Survey, which is contained in Appendix D. The instructors at FTC San Diego and the technicians aboard the USS SIDES (FFG-14) were provided copies of the survey in September 1994. The technicians' responses is due in by December 1994.

The maintainers of the MAES can obtain the technicians' opinions about their use of MAES directly from the surveys. These surveys can provide data to the maintainers with regards to the user's interface, accuracy of the system, and recommendations for enhancements. It is strongly recommended that these surveys be gathered and analyzed. If the data gathered from the surveys suggests that changes need to be made, then those changes should be incorporated into a later version of MAES.

4. Follow on Research

The USS SIDES (FFG-14) is assisting NPS in further evaluation of the hardware issue of portability. The ship is comparing the performance of a notebook and desktop computer while using both to operate MAES. The evaluation should be completed by December 1994. The results of the evaluation will be included in a master's thesis by a future project member at NPS.

Currently, the MAES Prototype 1.0 is being evaluated by the MK 92 Mod 2 FCS instructor staff at Fleet Training Center, San Diego, CA, for the feasibility of incorporating the MAES into the MK 92 Mod 2 FCS course of instruction at the center. Follow on research with regards to using MAES during formal training at FTC is recommended.

APPENDIX A: OLIVER HAZARD PERRY (FFG-7) SHIP INFORMATION

APPENDIX A: OLIVER HAZARD PERRY (FFG 07) SHIP INFORMATION

SHIP (USS)	HULL NBR	HOMEPORT	MK92 MOD	ATIS S/W	ATIS H/W
O.H. Perry	7	Staten Island	2		
McInerney	8	Mayport	2		
Clark	11	Newport	2		
S.E. Morison	13	Charleston	2		
Estocin	15	Philadephia	2	YES	YES
C. Sprague	16	Staten Island	2		
Antrim	20	Mayport	2		
Fharion	22	Charleston	2		
Boone	28	Mayport	2		
Stark	31	Mayport	2	YES	YES
A. Fitch	34	Mayport	2		
Underwood	36	Mayport	2	YES	YES
Doyle	39	Mayport	2		
Halyburton	40	Charleston	2		
Klakring	42	Charleston	2		
De Wert	45	Charleston	2		
Nicholas	47	Charleston	6	YES	YES
R.G. Bradley	49	Charleston	2		
Taylor	50	Charleston	6	YES	YES
Carr	52	Charleston	6	NO	YES
Hawes	53	Charleston	6	YES	YES
Elrod	55	Charleston	6	YES	YES
Simpson	56	Newport	2	YES	YES
S.B. Roberts	58	Newport	2		
Kauffman	59	Newport	6	YES	YES

Table A-1 Atlantic Coast Ships

SHIP (USS)	HULL NBR	HOMEPORT	MK92 MOD	ATIS S/W	ATIS H/W
Wadsworth	9	Long Beach	2		
Duncan	10	San Diego	2		
G. Philip	12	San Diego	2	YES	YES
Sides	14	San Diego	2		
J.A. Moore	19	San Diego	2	YES	NO
L.B. Puller	23	San Diego	2		
Copeland	25	San Diego	2		
M.S. Trisdale	27	San Diego	2		
Reid	30	San Diego	2		
Jarrett	33	San Diego	2		
Rentz	46	San Diego	2		
Vandegrift	48	San Diego	6	YES	YES
Gary	51	San Diego	6	YES	YES
Ford	54	San Diego	6	YES	YES
Ingraham	61	San Diego	6	YES	YES

Table A-2 Pacific Coast Ships

SHIP (USS)	HULL NBR	HOMEPORT	MK92 MOD	ATIS S/W	ATIS H/W
Flatley	21	Mobile	2	YES	NO
J. Williams	24	Pascagoula	2		
Gallery	26	Pascagoula	2	YES	YES
S.W. Groves	29	Pascagoula	2		
J.L. Hall	32	Pascagoula	2		

Table A-3 Gulf Coast Ships

SHIP (USS)	HULL	HOMEPORT	MOD	ATIS S/W	ATIS H/W
Crommelin	37	Pearl Harbor	2		
Curts	38	Yokosuka	2		
McClusky	41	Yokosuka	2		
Thach	43	Yokosuka	2		
Rueben James	57	Pearl Harbor	6	YES	YES
Rodney Davis	60	Yokosuka	2		

Table A-4 Out of CONUS Ships

APPENDIX B: MK 92 MOD 2 FCS MAES PROTOTYPE 1.0 USER'S MANUAL

I. INTRODUCTION

The MK 92 Mod 2 Maintenance Advisor Expert System, herein referred to as MAES, was developed for Naval Sea Systems Command, Naval Surface Warfare Center Branch, Port Hueneme, California, by faculty and graduate students at the Naval Postgraduate School, Monterey, California. MAES was developed using IBM PC-AT 80486 compatible computers running MS-DOS 6.2 operating system, Microsoft Windows 3.1, Microsoft Access database, and the expert system shell Symbologic Adept 2.11 and 2.2.

The primary goal of the expert system is to assist fire control technicians in the fleet to correctly diagnose complex casualties in the MK 92 Mod 2 Fire Control System. The MAES will increase operational readiness by giving the technicians "expert" knowledge through the use of a computer program. Use of the MAES will result in great economic savings for the Navy by reducing the costs of unnecessarily replaced parts and the cost of travel and accommodations of NAVSEA technical experts traveling to the ships in need of expert assistance.

MAES will assist in locating numerous faults in Performance or Calibration the daily systems operability test (DSOT). RF Power Checks will be included in a later version of MAES.

II. SYSTEM REQUIREMENTS

MAES will operate on a computer running Microsoft Windows 3.0 or 3.1. Specifically, the minimum requirements for running MAES are:

- An IBM PC-AT 80286 or compatible computer.

- Two megabytes (MB) of memory (RAM).

- A hard disk drive with 15 MB of free storage space.

- Microsoft Windows 3.0 or higher.

- MS-DOS version 3.1 installed.

- A 3.5 inch 1.44 MB floppy drive.

- A monitor that is supported by Windows.

- External mouse or built-in trackball.

As stated, these are minimum requirements. For maximum performance, it is highly recommended that the MAES be installed on an IBM PC-AT 80486, or compatible computer with 8 MB RAM, 120 MB hard drive, Windows 3.1, MS-DOS 6.2, VGA monitor, and mouse or trackball.

III. USING WINDOWS

A basic understanding of Microsoft Windows is needed to install and operate the MAES. This section briefly discusses Windows 3.1 basic operations:

- ◆ Starting and exiting Windows applications.

- ◆ Use of a mouse or other pointing device.

- ◆ Sizing, moving, and scrolling windows.

- ◆ Using pull-down and bar menus.

- ◆ Using commands and icons in the Windows Program Manager.

It is recommended that you read the Microsoft Windows User's Manual and complete the tutorial that accompanies your Windows software package. The tutorial can be accessed from the Program Manager window by clicking on **Help** and then clicking on **Window Tutorial** that appears on the pull-down menu. Other useful information about Windows is also available in the Help pull-down menu.

There are three basic elements of a Windows screen: desktop, windows, and icons. These elements are depicted in Figure 3-1.
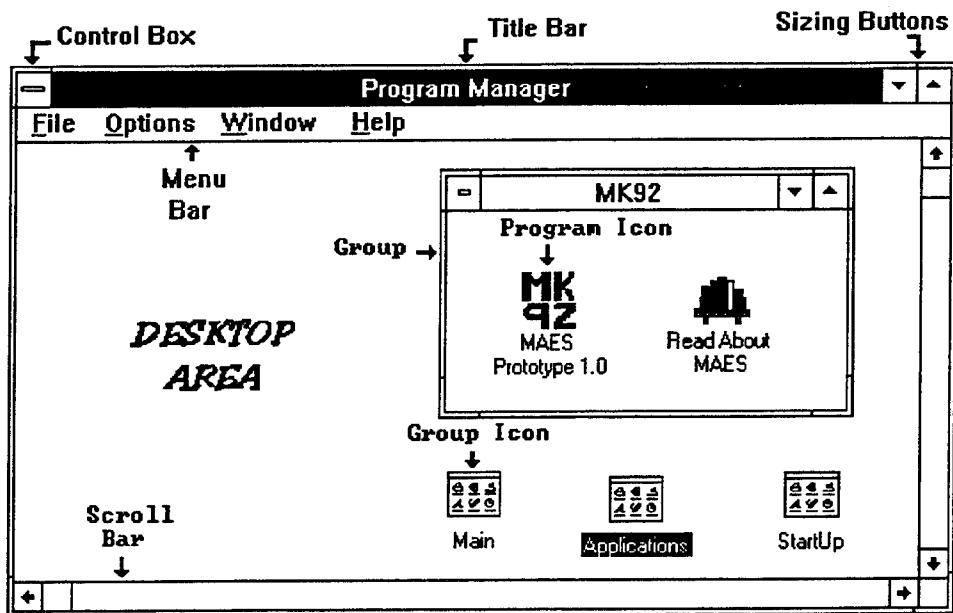
Figure 3-1 Microsoft Windows™ Program Manager Screen Display

A. DESKTOP

The desktop is the overall working area while running Windows. It can be thought of as the top of a desk. A window appears (opens) on the desktop every time a document is opened or an application is executed. This is similar to pulling out a file from a cabinet, placing the file on the desktop, and then opening up the file.

B. ICONS

An icon is a small symbol or picture that usually has a brief text description underneath. There are two types of icons: group and program icons. Group icons are used to represent groups of programs or documents.

Program icons represent individual programs inside a windows group. Programs or processes can be activated by double clicking on the icon using the left mouse or trackball button.

C. WINDOW

There are five basic elements of each individual window: control box, title bar, sizing buttons, menu bar, and scroll buttons. Each of the elements always remain in their respective locations around the window.

1. Control box

The control box is located in the upper leftmost corner of the window and resembles a drawer of a filing cabinet. The control box has two functions: opens a control menu and closes the window or application. The control menu is the menu that appears when a single click on an icon occurs. The menu allows for manipulation of the window. The window may be closed by double clicking on the control box or by selecting Close from the control window.

2. Title bar

The title bar is the narrow horizontal bar across the top of each window. The name of the running application or opened document appears centered in the title bar. The window can be relocated anywhere on the desktop by placing the cursor on the title bar, pressing and holding the left mouse button, and then pulling (dragging) the window by the title bar to the desired location. Once the window is in the desired location, the left mouse

button should be released. The title bar changes colors (or intensity) when any element of its respective window is activated by the mouse.

3. Sizing buttons

Each window has two sizing buttons: minimize and maximize. Both buttons are located in the upper right corner of the window. The left button has an arrow pointing down and is the minimize button. When this button is pressed, the window becomes an icon and is placed at the bottom of the desktop where it can later be reopened.

The right button has an arrow pointing up and is the maximize button. When the maximize button is pressed, the window expands and covers the entire desktop. Sometimes the maximize button appears as two arrows: one pointing up and one pointing down. In this instance, the button is called the restore button. When the restore button is pressed, the window is restored to its original size.

4. Menu bar

The fourth element of a window is the menu bar. The menu bar appears only on windows that have an application running. The menu bar stretches horizontally across the window just underneath the title bar. It contains a row of options that pertain to the application. A pull-down menu will appear when a single click on the left mouse button occurs on any of the words. Examples of options on the menu bar are **File**, **Window** and **Help**.

5. Scroll buttons

Scroll buttons appear on the bottom and right edges of windows that have a larger desktop area than can be seen. These buttons are used to scroll through the information in the window. These buttons are necessary when the graphics or text is too large to be viewed in the window.

IV. INSTALLING MAES

The installation of MAES can be accomplished using any one of the three methods discussed in this section; however, installation from the File Manager is recommended.

The installation program creates a new directory on your hard drive labeled **c:\MAES**, copies all the files from the MAES Prototype 1.0 installation floppy disk into the newly created directory.

During installation a windows program group called MK 92 is created. An icon representing MAES Prototype 1.0 is placed into the MK 92 group. The group and icon is depicted in Figure 4-1.
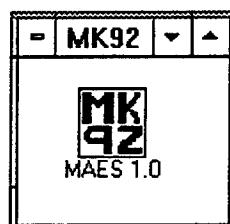
Figure 4-1 MAES Icon.

A.   FROM THE DOS PROMPT

1. Insert MAES Prototype 1.0 Installation Disk #1 into the A: drive.

2. Type **win a:instalit** and press Enter.

3. Proceed to Step 5 of Section C to continue with installation.

B. INSTALLATION FROM THE PROGRAM MANAGER

1. Insert MAES Prototype 1.0 Installation Disk #1 into the **A:** drive.

2. Select **File** from the menu bar.

3. Select **Run** from the pull-down menu.

4. Type **a:\instalit.exe** in the space provided.

5. Click on the **OK** button or press **Enter** on the keyboard.

6. Proceed to Step 5 of Section C to continue with installation.

C. FROM THE FILE MANAGER WITHIN THE PROGRAM MANAGER

1. Insert MAES Prototype 1.0 Installation Disk #1 into the **A:** drive.

2. Click on the **A:** drive icon in the File Manager's menu bar.

3. Wait for the files from the **A:** drive to appear in the right side of the window. Double click on **instalit.exe**, shown in Figure 4-2.
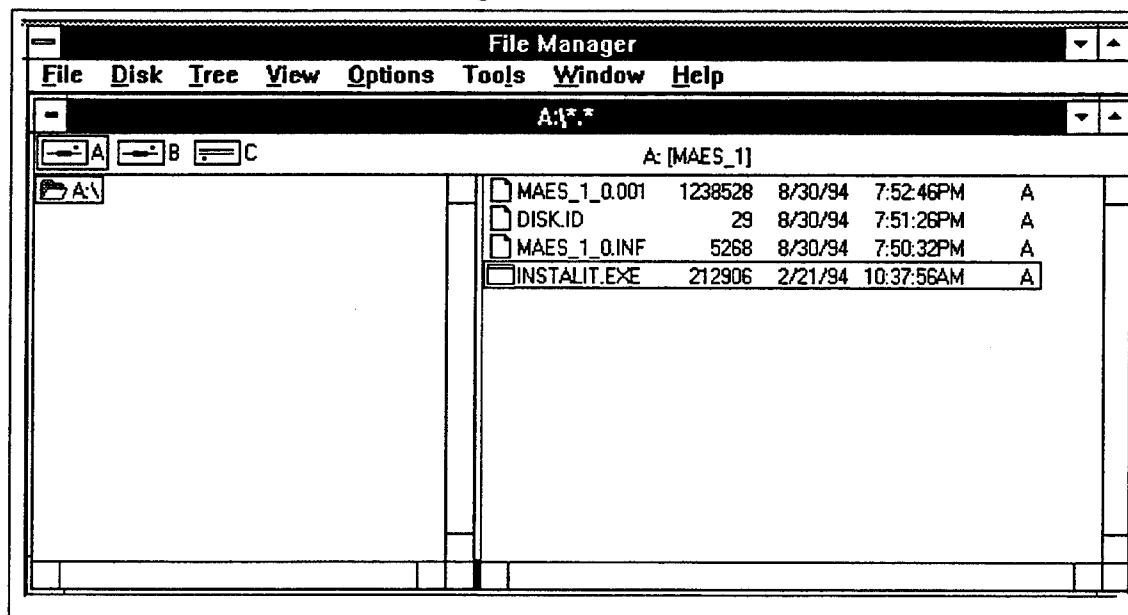
Figure 4-2 Instalit.exe File Location

4. Select **Install MAES Prototype 1.0** option, shown in Figure 4-3, and then click on **OK** or press **Enter**.

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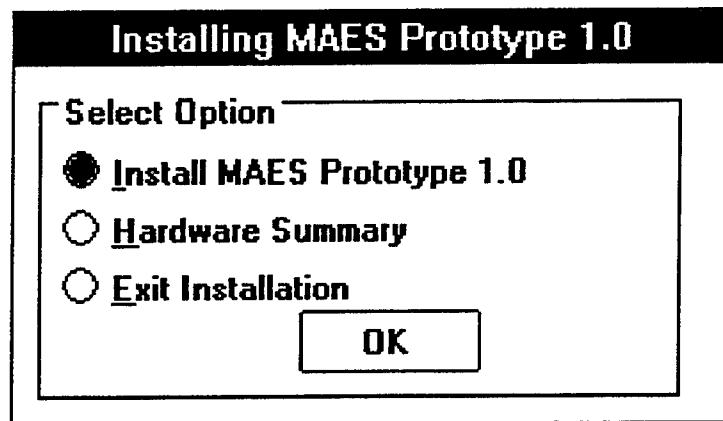
Figure 4-3 Installation Options Window

5. Select **C: local fixed drive**, as shown in Figure 4-4, and then click on **OK** or press **Enter**.

Figure 4-4 Select Installation Drive Window

6. The installation program gives you the option, as depicted in Figure 4-5, to change the preset installation directory, **C:\MAES**, but the MAES program will not operate properly if another directory is specified. Click on **OK** or press **Enter**.

```
┌─────────────────────────────────────────────────┐
│                    INSTALIT                      │
├─────────────────────────────────────────────────┤
│                                                  │
│      PLEASE CHOOSE YOUR INSTALLATION DIRECTORY   │
│                 ON A FIXED DRIVE                 │
│                                                  │
│      Make your choice and press <Enter> or click on OK │
│                                                  │
│  ┌────────────────────────────────────────────┐ │
│  │ C:\MAES                                     │ │
│  └────────────────────────────────────────────┘ │
│                                                  │
│                  ┌──────────┐                    │
│                  │ ✔ OK     │                    │
│                  └──────────┘                    │
└─────────────────────────────────────────────────┘
```
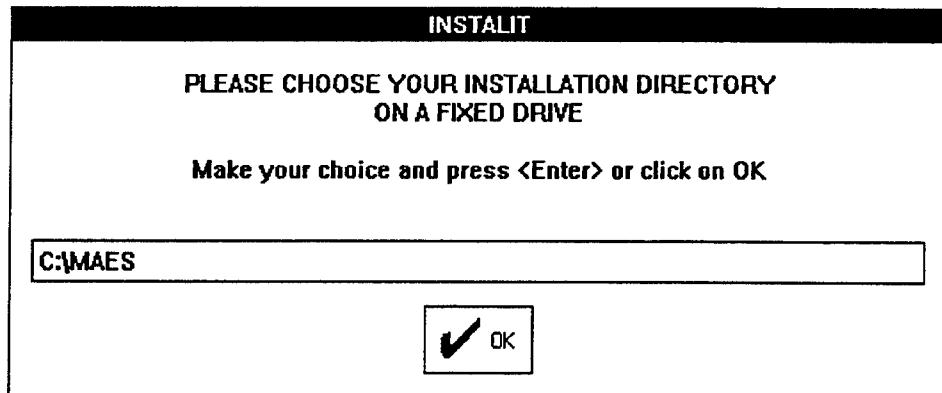
Figure 4-5 Installation Directory Window

7. The installation program will now begin extracting files from the installation Disk #1 and Disk #2 and place them in **C:\MAES** directory on your hard disk. NOTE: Pressing **ESC** key will terminate the installation procedure.

8. The installation program proposes adding **PATH=C:\MAES** to your autoexec.bat. Select **Go ahead and modify** and then click on **OK** or press **Enter**. This process is depicted in Figure 4-6.

```
┌─────────────────────────────────────────────────┐
│ ▬            How Shall We Handle It?             │
├─────────────────────────────────────────────────┤
│                                                  │
│  Changes could be necessary to the following system file(s). │
│                                                  │
│                  AUTOEXEC.BAT                    │
│                                                  │
│  If necessary, we can do them or you can do them. If we do │
│  them, we'll make a backup copy first. If you wish to make │
│  them, we will create example file(s) as a guideline for your │
│  changes. Choose "bypass" only if you're positive that the │
│  changes have already been made.                 │
│                                                  │
│              ◆ Go ahead and modify               │
│                Create example files              │
│                Bypass these changes              │
│                                                  │
│                  ┌──────────┐                    │
│                  │ ✔ OK     │                    │
│                  └──────────┘                    │
└─────────────────────────────────────────────────┘
```

Figure 4-6 Modification of Autoexec.bat File

9. As shown in Figure 4-7, the install program will prompt you to provide the drive that contains the **autoexec.bat** file. Most hard disks have this file in the root directory of drive **C:**. Select the appropriate drive and click on **OK** or press **Enter.**

```
┌─────────────────────────────────────────────────┐
│                   INSTALIT                       │
├─────────────────────────────────────────────────┤
│                                                  │
│      Please indicate your computer's true boot   │
│      drive. This drive's root directory should   │
│      contain the AUTOEXEC.BAT and CONFIG.SYS     │
│      files, if any.                              │
│                                                  │
│                    ┌───┐                         │
│                    │ C │                         │
│                    └───┘                         │
│                  ┌─────────┐                     │
│                  │  ✔ OK   │                     │
│                  └─────────┘                     │
│                                                  │
└─────────────────────────────────────────────────┘
```
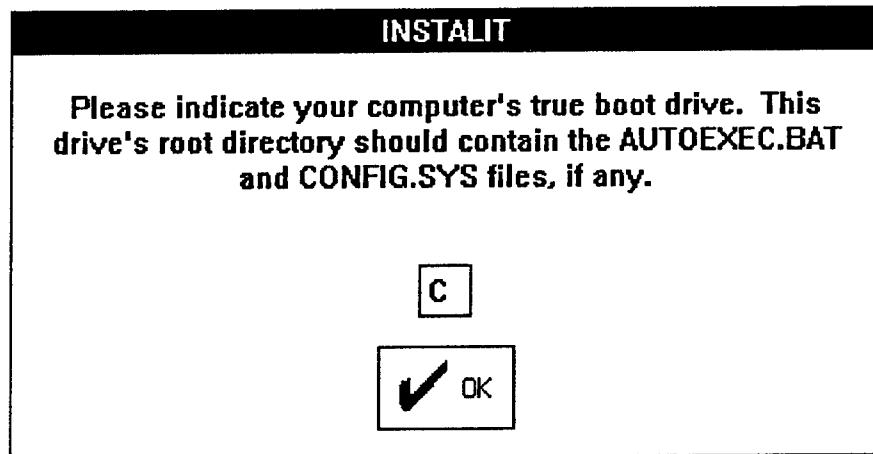
Figure 4-7 True Boot Drive Window

10. The installation program may next show you the complete path to your **autoexec.bat** file. If it does, simply click on **OK** or press **Enter**.

11. You have the option, as depicted in Figure 4-8, to install the MAES icon in an existing window group, not add an icon, or install the MAES icon into a new group called MK 92. It is recommended that you select **Or we can install Icon in a new group** option, then click on **OK** or press **Enter**.

```
┌─────────────────────────────────────────────────┐
│                 Install Icon                     │
├─────────────────────────────────────────────────┤
│                                                  │
│   ○ We can install Icon in an existing group     │
│                                                  │
│   ◉ Or we can install Icon in a new group        │
│                                                  │
│   ○ Or we can skip this part                     │
│                                                  │
│                ┌──────────┐                      │
│                │    OK    │                      │
│                └──────────┘                      │
│                                                  │
└─────────────────────────────────────────────────┘
```
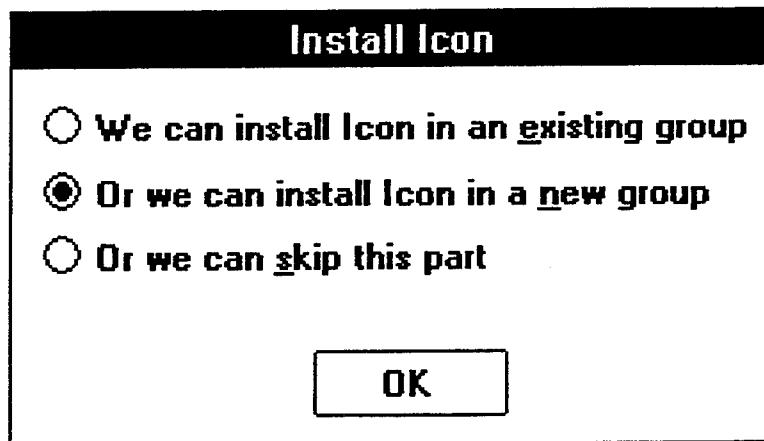
Figure 4-8 Installing Icon Window

12. The installation process is complete. The installation program will take you back to the Installing MAES Window, shown in Figure 4-2. Select **Exit Installation** and click on **OK** or press **Enter**.

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D. PROGRAM BACKUP

Back-up your MAES floppy disks immediately after installation! Setup gives you the choice of backing up you floppies or you can back them up by copying diskettes the conventional way. Store original MAES disks separately and securely away from the immediate computer area. Originals should not be stored with the backup disks.

V. STARTING & EXITING MAES

The MAES program may be started from the DOS prompt or through windows. Starting MAES through windows via the Program Manager is the recommended method. As previously illustrated, the MK 92 Group and MAES 1.0 icon are depicted in Figure 5-1.

A.   STARTING FROM THE DOS PROMPT

1. Type **win MAES** and press Enter.

B.   FROM THE PROGRAM MANAGER

1. Double click on the MK 92 Group icon .

2. Double click on the MAES 1.0 icon.

C.   EXITING MAES

You can exit MAES and return to the Windows' Program Manager by pressing the Exit button from the Main Menu display. To return to Windows at any time, do the following:

 ◆ Press and hold the **ALT** and press the **F4** key.

or

 ◆ Select the Control Box in the upper left hand corner of the window.

◆ Select the <u>C</u>lose option from the pull-down menu.

The MAES will display a message as shown in Figure 5-1 when either of the above

two methods are used to exit the program.
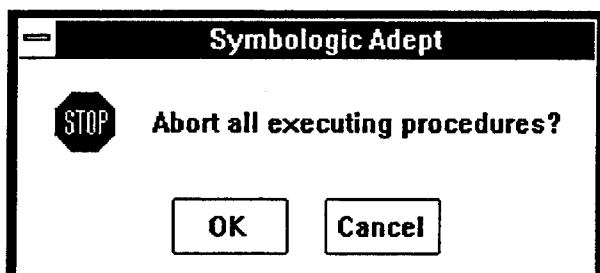
Figure 5-1 MAES Exit Message.

VI. USING MAES

This chapter provides you information about using MAES. The standard screen layout and its three basic parts are described. The second section discusses methods for providing input information to the program. This chapter concludes with a brief discussion on how you can receive helpful information while using MAES.

A.   SCREEN LAYOUT

The standard MAES screen is divided into three primary sections. These sections, depicted in Figure 6-1, are the title bar, procedure area, and action area. These sections are discussed next.
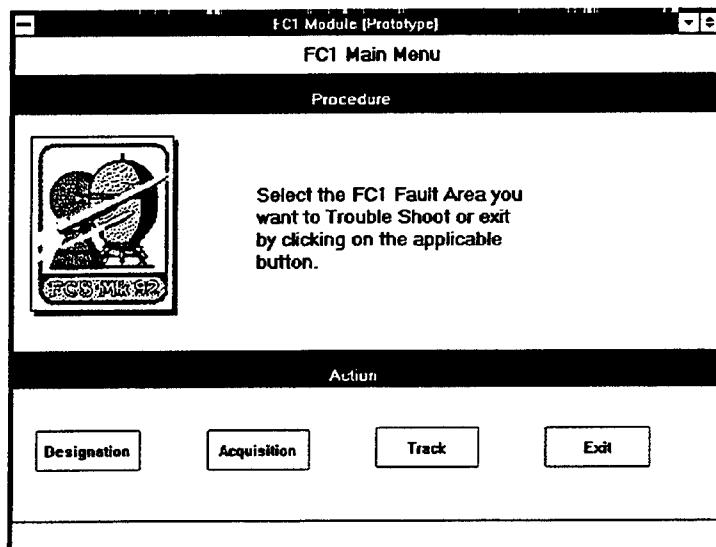
Figure 6-1 MAES Standard Screen Layout

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1. Title Bar

MAES has a title bar that is positioned horizontally across the top of each screen. The bar displays a title that represents where you are in the program. For example, the title depicted in Figure 6-1 is "FC1 Main Menu". This indicates that you are at the main menu of the Firing Channel 1 portion of the Performance section of the program. The title bar changes as you move around from one area of the program to another.

2. Procedure Area

The procedure area is the central portion of the display. It is separated from the title bar by a horizontal bar labeled "Procedure". The program uses this area to present you with instructions, procedures, and questions.

3. Action Area

This area is located in the bottom part of the screen. It is separated from the procedure area by a horizontal bar labeled "Action". This area allows you to interact with MAES usually by clicking a button.

B. INPUT METHODS

A display screen is a collection of graphical objects that allows you to input information to the program. The most common objects are buttons, list boxes, and check boxes. These objects are used to convey information to the program to display results, instructions, or complete a process. These objects are discussed next.

1. Buttons

You can select an option to direct the program by pressing a button. For example, when the button labeled "Prev Screen" in Figure 6-1 is pressed, the program displays the previous screen. Buttons appear on about every MAES screen. They represent a group of mutually exclusive options. You are allowed to select only one button at a time.

2. List Boxes

A list box is another method to interact with the program. It displays a list of choices that you may select one option from. If the list box has more choices than can be displayed in the box, you can use the scroll bars to view all of the contents of the list box. Only one item in a list box can be selected. An example of a list box is depicted in Figure 6-2.
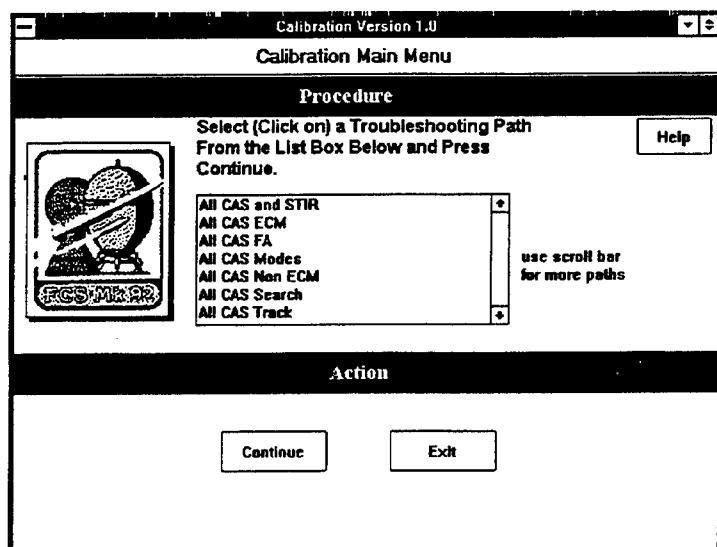
Figure 6-2   MAES Screen Using List Box

3. Check Boxes

A check box allows you to select or clear an option. You can select as many options by checking their corresponding check boxes. An "X" is placed in a check box when it has been selected. An example of check boxes in MAES is illustrated in Figure 6-3. Notice that six check boxes in the left column have been selected.

Calibration Version 1.0

Calibration Main Menu

Procedure

Select All Areas Which Show Failure,
Power Hi or Power Lo on the DSOT Printout,
then Press Continue.

Help

☒ STIR AFC Failure
☒ CAS AFC Failure

☒ CAS TR TGT FF ☐ STIR TGT FF ☐ CAS SR TGT FF
☒ CAS TR CLT FF ☐ STIR CLT FF ☐ CAS SR CLT FF
☒ CAS TR ECM FF ☐ STIR ECM FF ☐ CAS SR ECM FF
☒ CAS TR TGT FA ☐ STIR TGT FA ☐ CAS SR TGT FA
☒ CAS TR CLT FA ☐ STIR CLT FA ☐ CAS SR CLT FA
☒ CAS TR ECM FA ☐ STIR ECM FA ☐ CAS SR ECM FA

Continue   Exit

Figure 6-3 MAES Screen Using Check Boxes

C.   HELP INFORMATION

This section discusses the three types of help information that you can obtain from MAES. These types include "How", "Why", and "Parts Info" information. See Figure 6-4.

```
┌──────────────────────────────────────────────────────────────────┐
│ ─              Calibration Version 1.0                    ▼ │ ⬍ │
├──────────────────────────────────────────────────────────────────┤
│                    STIR Track Target Modes                        │
├──────────────────────────────────────────────────────────────────┤
│                        Procedure                                   │
├──────────────────────────────────────────────────────────────────┤
│  ┌──────────┐                                    ┌──────────┐     │
│  │          │   Replace                          │   How    │     │
│  │          │   UD 432/A1A5-A3, -A4              └──────────┘     │
│  │          │   UD 441/A3F1-A/03, A/06,          ┌──────────┐     │
│  │          │                                    │   Why    │     │
│  │          │                                    └──────────┘     │
│  │          │                                    ┌──────────┐     │
│  │          │                                    │ Parts Info│    │
│  │          │                                    └──────────┘     │
│  │          │                                                     │
│  └──────────┘                                    ┌──────────┐     │
│                                                  │Prev Screen│    │
│                                                  └──────────┘     │
├──────────────────────────────────────────────────────────────────┤
│                          Action                                    │
├──────────────────────────────────────────────────────────────────┤
│                      ┌──────────┐                                  │
│                      │ Continue │                                  │
│                      └──────────┘                                  │
│                                                                    │
└──────────────────────────────────────────────────────────────────┘
```
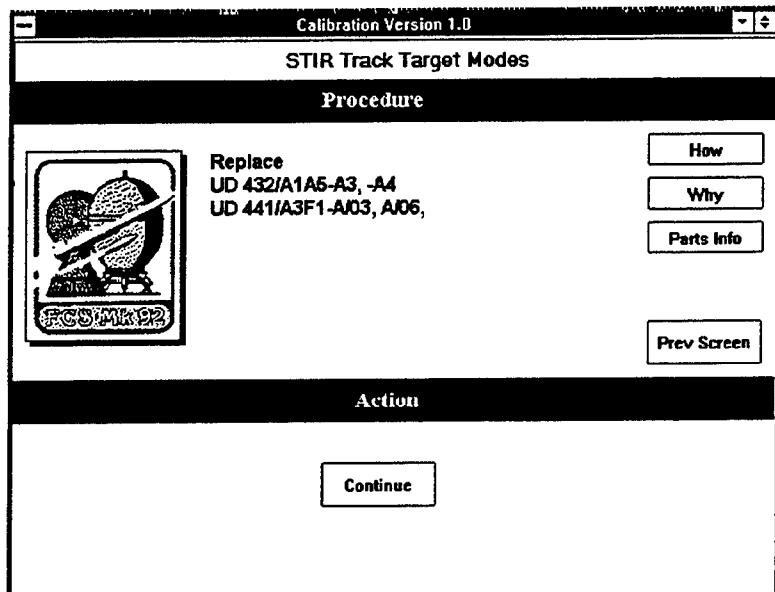
Figure 6-4 MAES Screen Using Help Buttons

1. How

This help feature provides you a detailed description of how to perform a required procedure. Once you press a button labeled "How" in the procedure area, a new screen appears with the information you requested. If there is more information than can be displayed in one screen, it will appear in a scrollable windows. Use the scroll bars to read the complete text.

2. Why

The "Why" help feature explains why MAES is directing you to perform a certain task. To receive a detailed "Why" explanation, press the button labeled "Why". A new screen appears with the help information. Once you finish reading the explanation, press "Return" and the program will take you back to the previous screen.

3. Parts

This help feature will give you parts information with regards to the part MAES is recommending to replace. To get the parts information, press the button labeled "Parts Info". It will provide you with a part number, reference diagram number, and where the part is used elsewhere in the system. This help feature is incomplete in the MAES Prototype 1.0, but will be incorporated in a later version.

D. OTHER HELP

Most circuit cards in the MK 92 Mod 2 FCS can be replaced using a generic card replacement procedure. Certain rules, which are intuitive to Fire Control Technicians, must be followed after replacing a circuit card. Procedures for generic card replacement procedure and rules to follow after card replacement are available on-line, as depicted in Figure 6-5, by clicking on the Begin Program button on the opening display. Generic card replacement procedures are listed in this section for convenience.
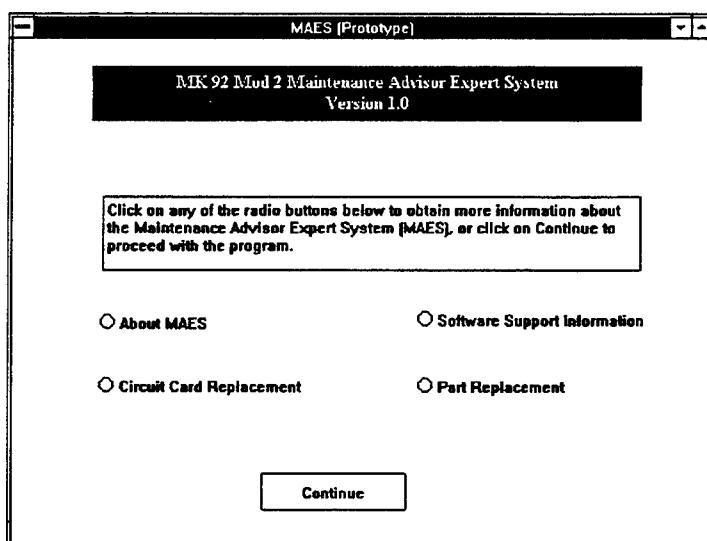

Figure 6-5 On-line Information

1. Generic Circuit Card Replacement

The generic circuit card replacement procedures, depicted in Figure 6-6, are as follows:

1. Remove and inspect card/cards for evidence of damage.

2. Replace damaged card/cards.

3. If inspection was o.k., reinstall card/cards and recheck previous test (ensure card/cards are seated properly).

4. If test still fails, replace card/cards one at a time beginning with the first card listed (most apt to fail) and recheck test.

5. When available, use identical card/cards from other locations as test replacement cards.

6. If test still fails after all cards have been replaced, check circuit associated with cards.
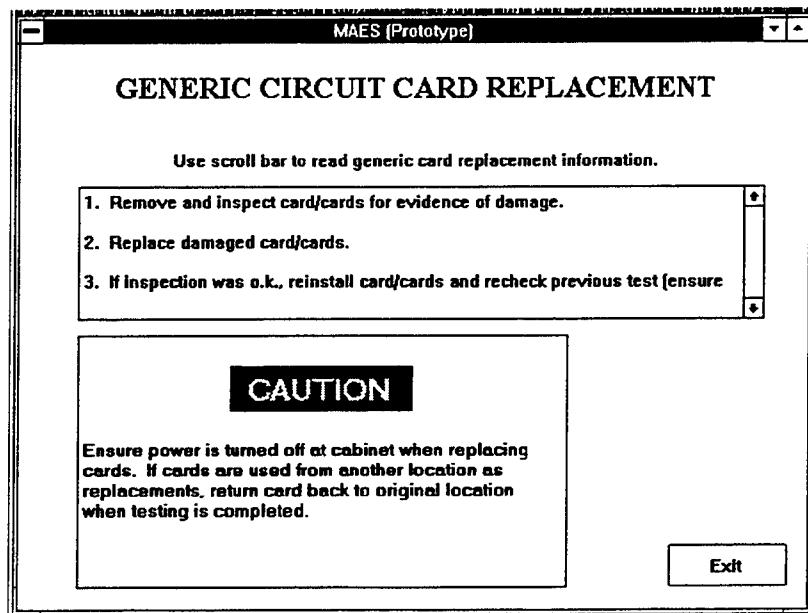

Figure 6-6 Generic Circuit Card Replacement Display Screen

2. Rules When Exiting After Part Replacement

The rules that should be followed after a part is replaced can be viewed on-line by selecting the Parts Replacement button depicted in Figure 7-1 and are as follows:

1. If an adjustment is performed in the path where the part is to be replaced, exit and perform the adjustment again.

    a. If the adjustment can be performed within specifications, rerun DSOT.

    b. If the adjustment still can not be performed within specifications, return to the display screen for part replacement and replace the next part listed. Perform the adjustment again.

    c. If all parts have been replaced and adjustment is still out of specifications, return to the screen display for part replacement. Obtain the figure reference for the signal flow diagram associated with parts and continue with troubleshooting.

2. If an adjustment is not performed in the path where the part is replaced, exit to submenu display screen and check to see if the problem is corrected.

    a. If the problem is corrected, rerun DSOT.

    b. If the problem is not corrected, return to the screen for part replacement and replace the next part listed. Check and see if the problem is corrected.

    c. If all parts have been replaced and the problem still exists, return to the screen for part replacement. Obtain the figure reference for the signal flow diagram associated with the part and continue troubleshooting.

NOTE: When returning to the adjustment screen or submenu display screens, make certain that the initial setup is completed before performing an adjustment or when checking to see if the problem is corrected.

VII. SAMPLE SESSION USING MAES

The following sample session is a realistic example of how to use MAES for troubleshooting a fault. The example assumes a failure in the Calibration module which has failure in all CAS Track modes.

A.   BEGIN THE PROGRAM

Start MAES by following the steps previously discussed in section V. To begin the program, click once on the button labeled Begin Program on the opening screen.

B.   SELECT A MODULE

The next screen that appears is called the MAES Main Menu and is depicted in Figure 7-1. Since this example demonstrates a Calibration CAS Track failure, press the Calibration button in the lower left portion of the Action area of the screen.
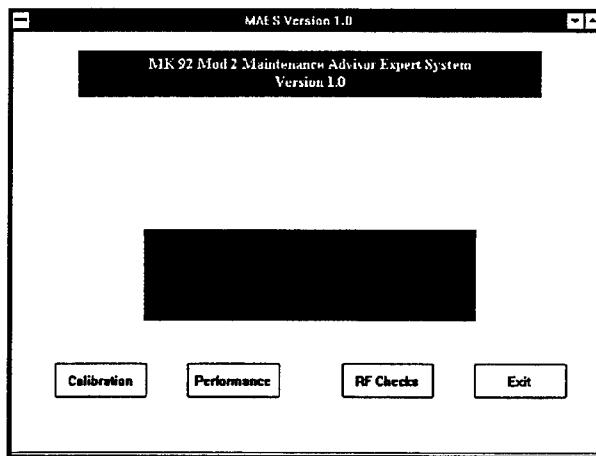

Figure 7-1 MAES Main Menu

Once the Calibration button is pressed, the Calibration Opening Screen, depicted in Figure 7-2, is displayed. You are given the option to exit back to the MAES Main Menu or continue into the Calibration Module. Press the button labeled Continue. The Calibration Main Menu, depicted in Figure 7-3, is displayed.
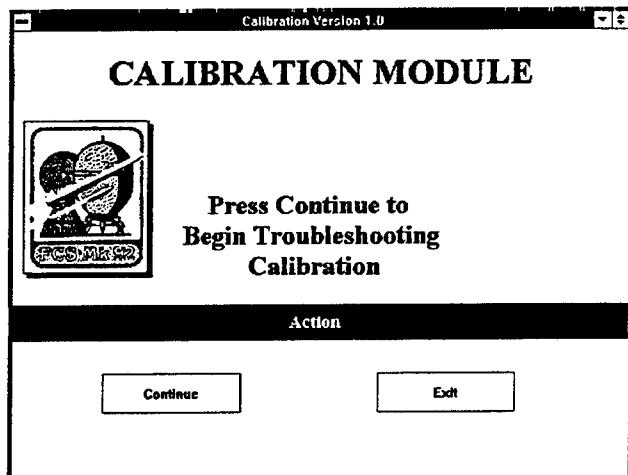

Figure 7-2 Calibration Module Opening Screen
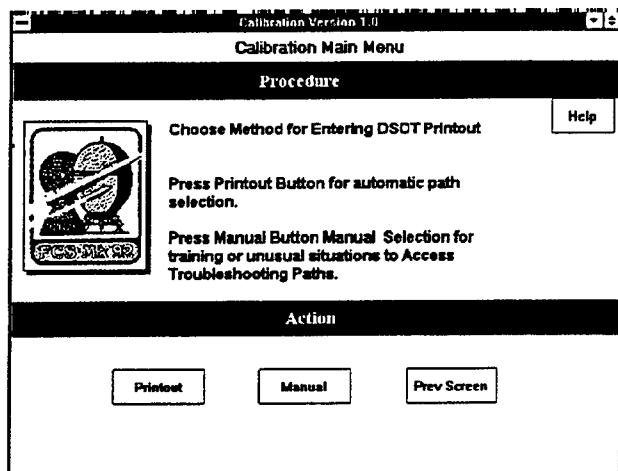
Figure 7-3 Calibration Main Menu

1. Select DSOT Entry Method

Two options for entering DSOT data are available in the Calibration Main Menu: Printout and Manual. The Printout option allows you to select problem areas on a display screen, shown in Figure 7-4, that mimics a DSOT printout. Press the button labeled "Printout".
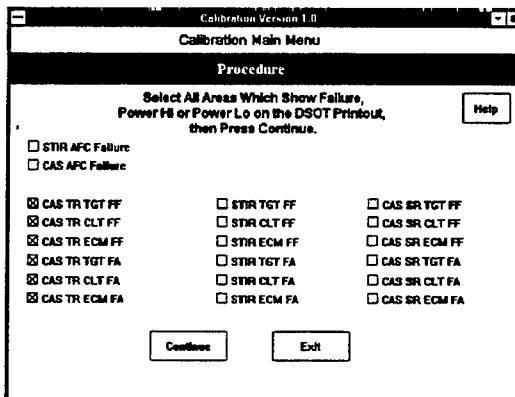
Figure 7-4 Calibration DSOT Printout Menu

2. Select Failed Areas

The next step is to select the failed areas by using check boxes in the Printout Menu. Check the six boxes shown in Figure 7-4 that are labeled CAS TR TGT FF, CAS TR CLT FF, CAS TR ECM FF, CAS TR FA, CAS TR CLT, and CAS TR ECM FA. Make certain that an "X" appears in each box. Checking these boxes informs MAES that multiple CAS Track failures exist.

3. Perform Tasks

Once the check boxes have been selected, press the Continue button on the Calibration DSOT Printout Menu. The next screen is depicted in Figure 7-5. MAES asks

if a power HI condition exists for all track modes. Our example simulates a Power HI condition for all Track modes, so press the Yes button in the action area. This action causes MAES to display another task screen as shown in Figure 7-6. This task requires to measure Track RF Power at the output of UD 412/A1A6-FL1. If you require help on how (or why) to perform this procedure, you can request on-line help as explained in the next section.
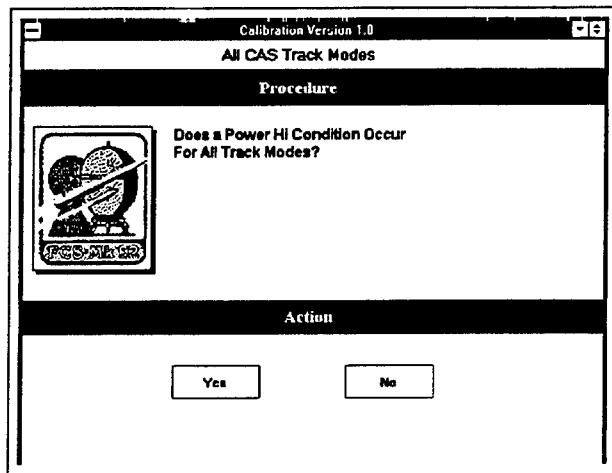

Figure 7-5 Power HI Task Screen
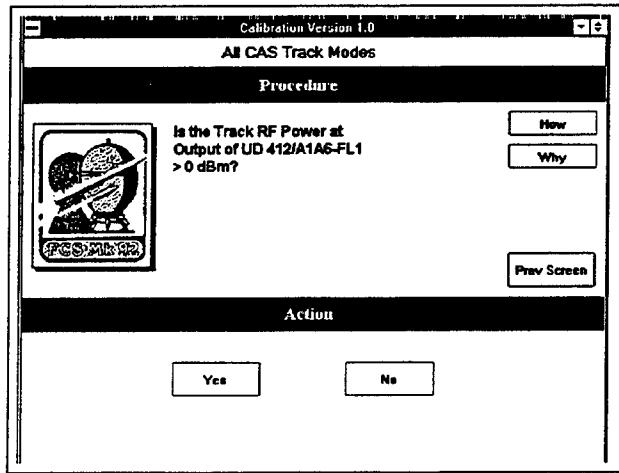
Figure 7-6 Measure Track RF Power

4. Getting Help

Press the button labeled "How" as shown in Figure 7-6. MAES will give you detailed instructions on how to measure Track RF Power at the output of UD412/A1A6-FL1. A partial view of the information is depicted in Figure 7-7. Use the scroll bars to read the entire set of instructions.

```
┌─────────────────────────────────────────────────┐
│           STIR Fixed Frequency Modes              │
├─────────────────────────────────────────────────┤
│                   Procedure                       │
├─────────────────────────────────────────────────┤
│ 1. Verify that FCS is not in radiate condition.  ▲│
│                                                   │
│ 2. Request WCO authorization for DSOT local mode  │
│ tests.                                            │
│                                                   │
│ 3. At DSOT test set UD432 verify that AC ON lamp  │
│ is in off condition. If not pull                  │
│ out AC POWER Circuit breaker.                     │
│                                                   │
│ 4.Release test set assembly from cabinet and      │
│ place in servicing position.                      │
│                                                   │
│ 5. Remove cable connector W25P13 from J2 of       │
│ A1A3-A3. Connect power                            │
│ measuring set to J2.                              │
│                                                   │
│ 6. Depress AC POWER circuit breaker on UD432 to   │
│ illuminate AC ON lamp.                            │
│ Verify that RADIATE and REMOTE lamps are          │
│ extinguished.                                    ▼│
└─────────────────────────────────────────────────┘
              ┌──────────┐
              │  Return  │
              └──────────┘
```

Figure 7-7 Help Screen (How to Measure Track RF Power)

Once you have finished reading the help information, press the button labeled "Return". The program would return to the previous screen (Figure 7-6). Now press the button labeled "Why". MAES gives you a concise reason why you are instructed to perform this measurement. The Why screen is depicted in Figure 7-8. After reading the steps in the Why display, exit back to the Measure Track RF Power screen by pressing the button labeled "Return".

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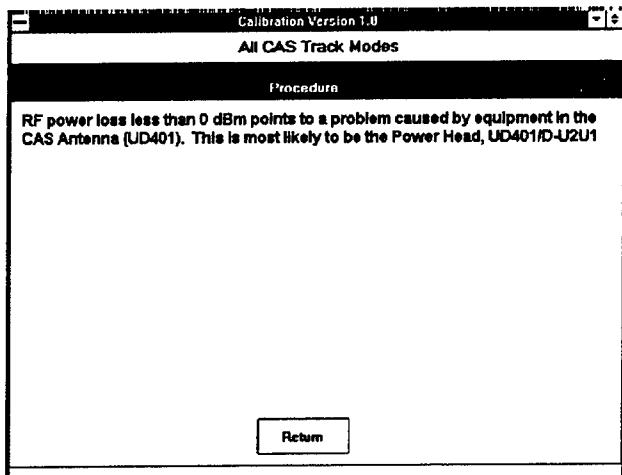
Figure 7-8 Help Screen (Why Measure Track RF Power)

Press the button labeled "Yes" as shown in Figure 7-6. The next screen, shown in Figure 7-9, instructs you to measure TTL Remote Mode Logic Levels at UD 412/A1A6-A13. Press the button labeled "Yes". This action causes MAES to display another task screen, shown in Figure 7-9, that requests you to Measure TTL Levels.
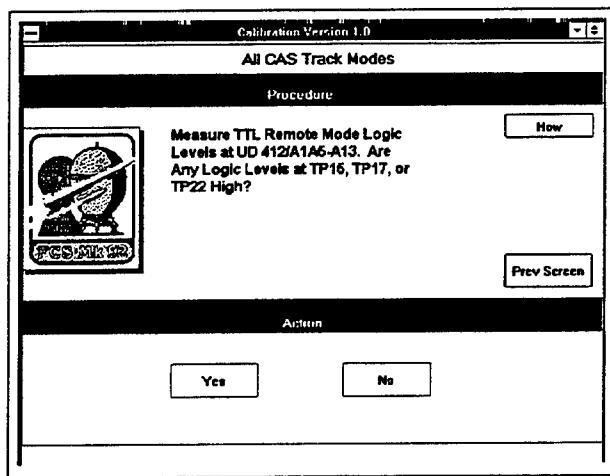

Figure 7-9 Measure TTL Levels

5. Replace Failed Part

An all CAS Track Failure in the example indicates that a logic level at TP15, 1P17, or TP22 is high. Therefore, press the button labeled "Yes". This action causes MAES to display the Replace Parts Screen as depicted in Figure 7-10.
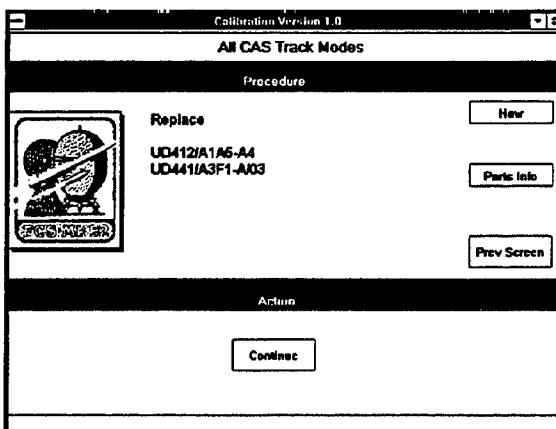
Figure 7-10 Replace Parts Screen

Press the button labeled "Continue" to return to the Calibration Main Menu.

You may now exit MAES. This concludes our sample session.

NOTE: Pressing the Continue button in a replacement type screen takes the user back to the beginning of the troubleshooting module. All data regarding the particular casualty will be reset by MAES.

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VIII. DOCUMENTATION AND TECHNICAL SUPPORT

Technical support regarding MAES may be received from representatives at NAVSEA, the Naval Postgraduate School, and UNISYS. The representatives can be reached by mail, telephone, or by GENADMIN message.

A. NAVSEA ASSISTANCE

Hardware and software technical support may be obtained from the NAVSEA technical representatives at the Naval Surface Warfare Center, Port Hueneme Division. The NAVSEA point of contact is Mr. Henry Seto, and he can be reached at:

> **Mr. Henry Seto (Code 4W32)**
> **NSWC Division**
> **4363 Missile Way**
> **MK 92 FCS Office, Bldg. 1211**
> **Port Hueneme, California**
> **93043-4307**
>
> **(805) 982-0141 commercial or**
> **551-0141 A/V**

Message Address:

RUWFPBC/ NAVSURFWARCENDIV PORT HUENEME CA//4W00//

B. NAVAL POSTGRADUATE SCHOOL

Questions regarding the development of the MAES Prototype 1.0, this user's manual, future enhancements, and project support should be directed to the Naval

Postgraduate School (NPS). The point of contacts are Professors Magdi Kamel and

Martin McCaffrey. They can be reached at:

Department of Systems Management
Naval Postgraduate School
555 Dyer Road
Monterey, California 93943
(408) 656-2494 or (408) 656-2488

C.   UNISYS

The expert knowledge contained in the MAES Prototype 1.0 is developed by Mr.

Dorin Sauerbier of UNISYS Corporation. Questions concerning the way the MAES

reaches a conclusion, or any other information contained within the program, should be

directed to Mr. Sauerbier at:

UNISYS
5151 Camino Ruiz
Camarillo, CA 93010
Attention: Dorin Sauerbier Code G-103

(805) 987-9317

APPENDIX C: NOTEBOOK COMPUTER TECHNOLOGY

APPENDIX C: NOTEBOOK COMPUTER TECHNOLOGY

A. OVERVIEW

This appendix discusses basic technologies used in portable computers, which are the primary factors to consider when selecting a portable computer. The primary factors to consider are: type of screen display, ability to expand (upgrade), keyboard and cursor positioning device, type of central processing unit, power management ability, and the type of battery. The appendix concludes with a brief discussion of minimum features a portable computer should have when used in shipboard applications.

B. SCREEN DISPLAY TYPES

There are several types of screen displays on the market today. First, video monitors used in desktop computers, are called cathode ray tubes (CRTs). These monitors require a large electron tube to create and present the video. Obviously, portable computers can not house a large device such as a CRT. Therefore, portable computers require different screen technology. Display screens used in portable computers are flat and much smaller than their desktop counterparts. The average portable display does not compare to CRT quality. However, as will be discussed later, active-matrix displays are comparable to CRT quality.

Both the CRT and flat display screens consist of a large number of pixels embedded on their respective screens. A pixel is a tiny dot that makes up the characters

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and graphic images on a display. The higher the number of pixels a screen can display the sharper the image and therefore the better quality the display screen. This quality is called the screen's resolution. Resolution varies among the three graphic types of screens: color graphics adapter (CGA), enhanced graphics adapter (EGA), and video graphics array (VGA).

A CGA display has a screen resolution of 320 by 200, i.e., 320 pixels per row with 200 rows. CGA technology uses only four colors. EGA displays have a screen resolution of 640 by 350 and use 16 colors from a palette of 256. Both CGA and EGA displays are the oldest in screen technologies.

Video graphics array (VGA) display screens are what most desktop monitors and portable displays use today. The screen resolution is 640 by 480 and can display 256 colors simultaneously. VGA technologies on black and white screens emulate color by varying shades of gray.

Screen resolutions go as high as 800 by 600 with some having resolutions as high as 1024 by 768. These are called Super VGA (SVGA) displays. SVGA displays are not yet available on notebook computers.

1. Standard LCD

The liquid crystal display (LCD) is the most common display technology for portable computers. It uses a liquid substance between two transparent electrodes. The molecules in the liquid form a crystalline pattern that polarizes the light passing through it whenever an electric current is applied to the electrodes.

Typical response time for standard LCD screen is about 300 milli-seconds. Response time refers to the display's ability to refresh the text or graphics. Ordinary LCD screens have significantly improved in quality over the last few years, but a 300 milli second response time is still too slow to keep up with moving images such as a cursor driven by a mouse, which sometimes disappears when it is moved quickly across the screen. This pointer problem is called submarining. For this reason, most notebook computers today avoid standard LCD and employ passive-matrix or active-matrix displays.

2. Passive-Matrix

Most passive-matrix screens use a single scanning process. Passive-matrix displays use only one transistor to control an entire row of pixels. This provides for less drain on the battery. Their screen size is usually bigger than active-matrix screens. A typical screen size is 9.5 inches diagonally. However, these types of screens have a very limited viewing angle. The user must look almost directly at the screen to see the display clearly. Passive-matrix color LCDs add about $500 to $800 to the price of a portable computer. The contrast ratio, which is how well something stands out from its background, on monochrome passive-matrix is about 12:1. This ratio is just above the minimum required by MIL-STD-1472D.

3. Dual-Scan

Dual-scan (sometimes referred to as double-scan) technology splits the screen into two halves and refreshes each half independently at twice the traditional speed. The

pixel matrix is divided into two horizontal segments with 240 rows each. This technology provides sharper color, reduced smearing, and reduced submarining. The image quality of this rather new technology falls between passive-matrix and active-matrix screens. The contrast ratio for dual-scan screens is typically about 18:1, a slight improvement over passive screens. However, there is one major drawback to dual-scanning -- a visible line may appear where the two halves of the screen meet.

Dual-scan technology makes less expensive passive-matrix color displays more acceptable and affordable. These displays are more expensive than standard passive-matrix displays.

4. Active-Matrix

The active-matrix type displays are the only type of displays that have refresh rates fast enough to keep up with a mouse. Active-matrix displays are sometimes referred to as thin-film transistor (TFT) screens. Unlike passive-matrix, they use separate transistors to control each pixel's red, blue, and green signals. A thin film of transistors is built directly on the glass housing of the screen. A TFT display uses over 900,000 transistors. The use of this technology provides for CRT-like color on notebook display. These screens are clear, crisp, and have vibrant colors. The contrast ratio for this type of display can be up to 60:1. That is significantly higher than dual-scan and passive displays.

Active-matrix color screens look sharp and clear at any brightness level. Unlike standard LCD, they are unaffected by surrounding light. However, there are at least three disadvantages to this technology: small screen size, high drain rate of battery, and cost.

A primary disadvantage of active-matrix color displays is that they are the most demanding of the battery. The reason is that active-matrix color uses a transistor for each pixel on the screen, and transistors are a big current drain on the battery.

Another disadvantage of active-matrix is the cost. The largest active-matrix color screen on the market today measures 10.4 inches and costs about $5,000. Color notebooks with a smaller 8.5 inch screens usually cost about $800 to $1500 more than a comparable passive-matrix model. The biggest factor in the cost difference is the difficulty making active-matrix color LCDs. It takes almost one million microscopic transistors to make an active-matrix display. This sophisticated technology makes the manufacturing process very difficult. Fewer than one in five screens pass defect free during manufacturing making this type of screen very expensive (Howard, 1993).

C. OTHER DISPLAY SCREEN CONCERNS

There are several other important factors to consider about a notebook computer's screen besides the screen display type. These points are: screen's size, the type of illumination employed with the screen display, how the screen is controlled or adjusted, and forthcoming screen technology. These factors are discussed next.

1. Screen Size

Screen size varies in notebook computers typically from 7.5 inches to 10.4 inches diagonally. The larger screens are most often found in standard LCD and passive-matrix displays. Screen size is directly related to power consumption and price. Smaller screens consume less power and are least expensive. However, the main disadvantage of a small

screen is the strain in viewing it. The average size screen for active-matrix notebooks is 8.5 inches while other types are typically over 9 inches.

2. Illumination

Manufacturers now place small fluorescent light sources on the side or behind an LCD panel to provide a brighter display. An illuminated screen is either sidelit, edgelit, or backlit. When viewing a screen at an angle, the active-matrix is much easier to view than passive-matrix screens.

Older types of color displays use reflective technology. Reflective displays rely on ambient light reflected through the LCD to illuminate the display. These types of displays require a light source to operate. The newest displays use transflective technology. Transflective displays have surfaces that are reflective and employ side lights. Transflective displays have lower contrast ratios than ordinary reflective sidelit displays.

3. Controls and Adjustments

Display controls and adjustments are features that are essential to a notebook's display and performance. Positions of the brightness and contrast controls should be comfortable to reach. In addition, the range of each control or adjustment should satisfactorily change the display from one end of the spectrum to the other. Thumbwheels and slider bars are the most common types installed on today's notebook computers. The least desirable type of controls are those that require two fingers to perform two keystroke combinations. For example, to adjust the brightness and contrast on the Zeos Contenda

486SL, the user must first press and hold a function key while pressing another key simultaneously.

4. Forthcoming Technology

New screen technology is being developed by 3M and Casio. 3M has developed a film that focuses the light is such a way that it is directed toward the user's eyes. This technology will greatly enhance visual acuity for the user once it is applied to notebooks. Casio is in the process of developing a flexible LCD panel that uses plastic instead of glass which will reduce the overall weight of the notebook.

D. EXPANDABILITY

The next technology factor to consider is the notebook's ability to expand. Owning a computer that is obsolete in just a year is frustrating to say the least. What is even more frustrating is owning a computer that can not be upgraded to keep it from being obsolete. Careful consideration should therefore be given to what technology is available and if the computer to be purchased can be upgraded or expanded for future technological advancements. For notebook computers, the current advancement issues are primarily miniature circuit cards and the computer's ability to interface with a desktop computer. A discussion of both issues follows.

1. PCMCIA

The Personal Computer Memory Card International Association (PCMCIA) was developed to make notebook and subnotebook computers expandable like desktop computers. PCMCIA, formed in 1989, is a non-profit trade and standards organization.

PCMCIA is the latest technology in portable computing. It establishes and maintains PCMCIA specifications. The 575 member international group is supported by over 300 companies (Rose, 1993). PCMCIA specifications define standards for the size of memory, modem, hard disk, and other input and output (I/O) devices for notebook computers. The association's goal is to have the ability for total compatibility between notebook computers. Once the goal is reached, cards may be swapped in and out of any notebook computer enabling new features and functions to be changed at an instant -- without powering down and rebooting. This capability is called plug-and-play.

The association was formed to solidify hardware standards and software interface requirements for removable memory cards and their receptacles. Two levels of software interfaces are defined by PCMCIA: Socket Service and Card Service. These services are designed to extend PCMCIA basic capabilities and ensure compatibility. PCMCIA calls the hardware circuit cards in their specifications PC cards. The current standard, PCMCIA 2.01, includes definitions for the PC cards and their slots.

Socket Service is a low level BIOS interface that manages the actual PCMCIA socket hardware. It is the standardized software connection between PC Cards and the application software. Therefore, Socket Service manages the recognition and use of the PC Cards. Card Service manages the PC Card itself and associated slot. Card Service is a software layer above the Socket Service. It coordinates access to the PC cards, sockets, and computer system resources. Socket and Card Service are in the form of drivers and must be installed in the system's CONFIG.SYS file. (Lefkowitz, 1994)

A PC Card is any memory or I/O peripheral card that meets PCMCIA standards. These cards are usually referred to as PCMCIA Type I, II, or III. The types refer to the card's thickness which are measured in millimeters (mm). The thickness of Type I, II, and III cards are 3.3 mm, 5 mm, and 10.5 mm, respectively. The cards are about the size of a credit card. All three types of cards have the same width (54 mm) and height (85.6 mm). Each is configured with a standard 68 pin connector for interchangeability. Any card will fit in its own type of slot or a larger type slot and can be removed or inserted without rebooting the system. Cards may be powered down while not in use. This is an advantage when working on a battery powered notebook.

Type I cards are primarily used as memory cards. Flash Memory, Static RAM, ROM, and DRAM are examples of the type of memory available. Flash memory is the newest type of storage and is erasable like conventional RAM. However, it is nonvolatile, i.e., continues to hold data after the power is turned off. (Rose, 1993)

Some applications can run directly from flash memory. This procedure is called execute in place (XIP). The XIP eliminates the need for large amounts of RAM. This is extremely useful in notebooks where space is at a premium. Using XIP may help reduce the cost of notebook by reducing the amount of required memory. (Rose, 1993) Flash memory cards use Electrically Erasable Programmable Read Only Memory (EEPROM), so they need no on-board power source. This feature will save power.

Type I cards are starting to be used as an alternative to hard disk storage. Since the cards have no moving parts, reliability is improved. Faster access times are also an

advantage of using the cards rather than conventional rotating disk drives. One disadvantage of a Type I card is cost. They are almost ten times the cost of their desktop counterparts. Another disadvantage is the card's size limits the amount of data storage. The size is limited to be approximately 200 megabytes.

Type II cards are primarily used in communication applications, i.e., data and fax modems, LAN adapters. These cards are about three times the cost of their desktop counterparts. Type II slots are the most commonly used in notebooks.

Type III cards are not as common as the Type II. Because of the extra thickness of the Type III cards, they are used for rotating hard disk drives. The cost per megabyte (MB) of storage is about $8 to $12 compared to $0.75 to $1.00 for a desktop disk drive.

Finally, a Type IV card, measures 16 mm in thickness. The Type IV card will be used for larger hard drives. These slots can hold up to three Type II cards or contain a larger hard drive than the Type III. It is being developed by Japan Electronic Industry Development Association Standard (JEIDA), but is not approved by PCMCIA as a standard. PCMCIA opposes the inclusion of Type IV into their standards because the association believes that Type IV PC cards are too large. Even though Type IV cards are not endorsed by PCMCIA, Toshiba is putting the 16 mm slots in one notebook model, Toshiba T4500. They advertise it as 16 mm PCMCIA 2.01 complementary. (Rohan, 1994)

Currently, the majority of PC Cards on the market are modems, dynamic RAM (DRAM), and Ethernet network adapters (Type II). The cards are becoming more

ruggedized. They can withstand several times the shock that similar desktop cards can absorb (Smarte, 1994). The cost is decreasing each year too. Unfortunately, not all vendors are in full support of PCMCIA standards which has resulted in numerous incompatible notebooks on the market.

2. Docking Stations

Docking Stations also provide expandability for the notebook. A docking station is an external chassis device that provides connection between a notebook computer and a desktop or peripheral devices. The docking station may provide the notebook with drive bays, adapter slots, and parallel or serial ports to attach to other devices. These devices include monitors, a mouse, or larger keyboards. Docking stations provide notebook and subnotebook computers access to desktop services at a cost less than that of a desktop.

Because of the dynamic growth of PCMCIA technologies, it is difficult to predict what cards will be needed, what will be developed in the future, and how compatibility issues will be resolved. Vendors of docking stations hope to manufacture their products to provide solutions to these problems.

E. KEYBOARD AND POINTING DEVICES

As previously stated, types of cursor positioning devices include: mouse, trackball, joystick, digitizing tablet, touch tablet, touch screen, light pen, and arrow keys on a keyboard. Pointing devices are necessary for computers running window applications. These various devices are discussed next.

3. Mouse and Trackball

A mouse, a hand-held device that is rolled on a tabletop to control the movement of the cursor, is nowadays a commonplace device. While the mouse is easy to use and is considerably fast, it takes up space and its cord sometimes gets in the way. Several vendors now offer a cordless mouse, which may clip-on to the side of the computer or be permanently side mounted. This type of mouse has the advantage of not taking up desktop space or have cords to get tangled.

A trackball is similar to a mouse in that instead of moving (rolling) the mouse, a ball mounted on top of the trackball is rolled. The trackball takes up less space, especially if it is physically mounted on the keyboard.

The position of the trackball is of great ergonomic importance. If the trackball is located in the upper right area of the keyboard like the Zeos Contenda, the user must hold his hand and wrist in an unnatural position to avoid pressing any key. The Apple's PowerBook trackball, which is placed on the horizontal surface of the keyboard just below the spacebar in a large wrist area, and has two oversized buttons surrounding the trackball, is much more comfortable and convenient to use.

4. Comparative Study of Pointing Devices

An ergonomic study of cursor positioning devices, compared speed versus accuracy of six devices (Sanders, 1987). The results showed that speed is almost inversely proportional to accuracy. A mouse was not evaluated in this study, but Sanders later

found that it is equally ranked with a trackball regarding speed and accuracy. The results of the study are listed in Table C-1.

Device	Speed	Accuracy
Touch Screen	1	5
Light Pen	2	5
Digitizing Tablet	3	2
Trackball	4	1
Joy Stick	5	3
Keyboard	6	4

Table C-1 Comparison Of Cursor Position Devices

The table shows that the touch screen cursor positioning device allows the user to position the cursor at the greatest speed (number 1), but it is the least accurate (number 5). The trackball allows the user to position the cursor with moderate speed, a speed ranking of four, but provides the user with the greatest accuracy.

5. New Pointing Device Technology

IBM has developed a new cursor positioning device called Track Point II. It is a pressure sensitive stationary joystick, wedged between the G, H, and B keys on a standard QWERTY keyboard. It moves the cursor with a touch of the either left or right index fingertip while the rest of the fingers stay on the home row keys. Buttons that function as left and right mouse buttons are located on the front edge of the notebook. The buttons can be pressed with the thumbs thereby allowing the user's hands to remain on the keyboard. IBM uses these devices on their IBM ThinkPad Notebooks and is currently licensing this technology to other vendors.

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F.   COMPUTING POWER

The next factor to consider is computing power. The brain of a computer, the central processor unit (CPU), is an integrated circuit (IC) chip, a miniature device composed of millions of miniature transistors, the newest of which has over three million transistors.

1. CPU Architecture

The dominant architecture of today's CPUs is called Complex Instructions Set Computing (CISC).   The entire x86 family for IBM and compatible computers, as well as Motorola's family of CPUs for the Apple Macintosh, are built using CISC architecture. A new CPU architecture is becoming available and is called Reduced Instruction Set Computing (RISC). Chips using this architecture have more simplistic sets of instructions and easier memory addressing.   However, RISC chips have a very sophisticated compiling process and are more expensive than CISC chips.

2. CPU Manufacturers

There are several basic microprocessor chips available for IBM and compatible portable computers. The processors come with various speeds and are produced by an array of manufacturers that are continuing to grow in number. Intel enjoys the biggest market share in CPU production. However, Intel is being forced to share more of the market with corporations such as: Advanced Micro Devices (AMD), Cyrix, IBM, and Motorola. Intel's CPU product line features: 386SL, 386SX, 486SL, 486SX, 486DX, and

Pentium. Intel dominates the processor market and hopes to keep it that way by continuing to improve their CPUs.

AMD and Cyrix make Intel clone chips for IBM compatible computers. Cyrix's version of Intel's 486 chips are named Cx486SLC and Cx486DLC. IBM has developed a new chip, IBM 486SLC2, is referred to as Blue Lightening.

3. Power Saving Chips

The microprocessor chips using SL technology, often referred to as power down chips, consume less power than the older SX and DX models. Most notebooks using SL type chips include features such as: a CPU sleep cycle, CPU slow-speed option for idle times, and hard disk spin down cycle when not in use. These features are highly desirable in portable computers that must rely on battery power. The SL processors are the most widespread chip used in current notebooks. Intel claims that all of their next generation of SX, DX, and DX2 chips will have built-in power saving features comparable to the SL chip.

4. Processing Speed

The processing speed of a computer, measured in mega-hertz (MHz), is significant in graphically oriented programs and database applications. A computer with a processor speed of less than 33 MHz, runs very slowly while performing intensive database and graphical functions.

Intel's Pentium chip is the fastest processor on the market, running applications nearly two times faster than DX/66 chips, with a processing speed up to 100 MHz. The

Pentium has built-in power management features and operates on 3.3 volts, but is not yet available in notebook computers.

The faster the processor does not necessarily mean that it is the best. For example, a recent test of 68 notebook computers, based on the CPU's interaction with main memory and cache, found that TI TravelMate 4000 using a DX2/50 processor outperformed its counterpart using a DX2/66 chip (Howard, 1993).

G. POWER MANAGEMENT

The highest percentage of overall notebook weight is the battery. Since portable computers need a good reserve of power and be lightweight, the challenge to manufactures is to provide users with power saving functions and develop or procure batteries that last longer and weigh less.

There are several power management features now available in notebooks. As previously stated, microprocessor chips using SL technology consume less power than the older SX and DX models. Lower voltage technology and power management software also prolong battery power.

1. Lower Voltage Technology

Until this year, the standard operating voltage for desktop, laptop, notebook, and subnotebook computers was 5 volts. Micro chip manufactures have developed a newer, more efficient microprocessor that operates on 3.3 volts. It is predicted that only 3.3 volt notebooks will be manufactured after 1994. Computers using 3.3 volt technology have longer battery lives. Using this technology, power consumption drops by 120 to 170

watts while the computer is running idle. Full power will be regained once the user touches a key or mouse. Screens and memory that use 3.3 volts vice 5 volts offer power savings up to 45 percent. This technology is well suited and much needed for portable computers, but it is also being applied to desktop models.

The 3.3 volt power for portable computers means longer times between recharging. Desktop computers using 3.3 volts are predicted to consume up to 50 percent less power from the older 5 volt models. The advantages of this new technology provide for computers that are smaller, weigh less, and have lower operating temperatures. In addition, the 3.3 volt standard is more reliable because it operates much cooler than 5 volt types.

There are two primary concerns about using this new technology: inadvertent voltage spikes and noise. Since conductors are much closer in this type of circuitry, there is a high potential for erratic voltage or current spikes traveling to the wrong device. In addition, the 3.3 volt circuits are sensitive to high frequency interference and require additional filtering circuits. All portable computers must be certified by the Federal Communications Commission (FCC) as Class B stating they will operate at approved noise levels. Class B and other Government regulations are discussed in some detail following in the next section.

2. Government Regulations

The FCC Class B identification number shows that an electronic device sufficiently meets low radio frequency emissions. All portable computers are required by

law to have a Class B certification and an identification number assigned. The FCC maintains its own computer bulletin board service that has information regarding certifications of different computer products. The bulletin board may be accessed using a standard 1200 baud modem operating under off-the-shelf communications software. The telephone number to dial is (301) 725-1072.

Another federal agency, the Environmental Protection Agency (EPA) is also getting more involved in the computer industry and products. The EPA has started a program called Energy Star that is designed to encourage manufactures of personal computers and peripherals to be more energy efficient. The program is voluntary and has participation by major companies such as IBM, Apple, DEC, HP, NCR, NEC Unisys, Zenith Data Systems, and Intel. (Rohan, 1993) The program is developed around the new power-down technology discussed in the previously in Section F.

3. Power Management Software

Intel, IBM, and Microsoft Corporations are jointly developing the Advanced Power Management (APM) software module for use with Microsoft Windows. APM can only be used with MS-DOS 5.0 and Windows 3.1 or higher versions. APM also works with OS/2 operating system. In both DOS and OS/2 versions, APM works with the operating system to control the system's hardware power management features and with the system's BIOS. Microsoft claims that using APM will extend battery life in a notebook computer by as much as 20 percent (Bauer, 1993). System management mode (SMM) is hardware that must be included in the CPU in order for the CPU to respond to

APM instructions. In essence, the SMM involves adding eight instructions to the CPU's instruction set. Intel has already included SMM in many of their CPUs.

H.   BATTERY POWER

The last technology addressed in this appendix is battery power. A major technological challenge facing portable computing vendors is providing enough battery power to run a portable computer while keeping the weight and cost down. Many portable computers on the market allow the batteries to be changed (swapped) without powering the system down. This process is called "hot-swap" and is a desirable feature for busy applications. Today's faster processors, additional memory, color displays, and disk drives all place extra demands and strain on batteries.

Most portables have the older nickel cadium (NiCad) batteries developed in the 1960s. A new nickel hydride (NiMH) battery is now available on the market at a much higher cost. The newest in battery technology is called lithium polymer, lithium ion, and zinc-air. There is no industry standard to date for battery type, size, or construction.

1. Battery Basics

Before discussing the various types of battery technology, an overview of battery basics is presented. A battery is an electrochemical device that stores chemical energy. The stored energy is converted to electrical energy on demand. The interior of a battery has two electrodes, one positive and one negative, and an electrolyte substance to allow ions to flow between the electrodes.

Battery life is the amount of total time that a battery operates before it needs to be replaced. It is usually expressed in hours. Run time is the amount of time a battery will operate (run) before a recharge is necessary.

Power represents the rate at which work can be done and is expressed in watts. Energy is the term given to represent how long a battery can sustain a given rate of power and is expressed in watt hours. Energy density is the amount of energy that is stored in a unit of weight or volume and is also expressed in watt hours per kilogram.

Vendors advertise an array of numbers about their particular battery's life. What the vendors do not state is under what conditions those numbers were achieved. Typically, with the screen on and no components in a sleep mode, the following current drains apply to active-matrix color, passive-matrix color, and black/white: 14 to 15 watts, 13 to 14 watts, and 10 to 11 watts, respectively. Calculation of battery life can be accomplished by dividing the battery's watt-hour rating by the numbers just mentioned. If the watt-hour rating is not written on the battery, it may be calculated by multiplying the voltage rating by the advertised ampere hour rating.

Most portable computers with color displays come equipped with a battery rated close to the average of 30 watt hours. Color notebook computers typically require 15 watts of power per hour. Therefore, a 30 watt hour battery will only last two hours (30 watt hours/15 watts = 2 hours) before recharging is necessary. A battery that lasts longer must have a higher watt hour rating which means added weight. Hence vendors opt for less battery weight and give up longer battery run times.

2. Nickel cadium (NiCad)

NiCad is the most popular, most inexpensive, yet least efficient battery type. These batteries contain a hazardous material called cadium and must be carefully disposed of. NiCad batteries need to be fully discharged (drained) before recharging to avoid accumulation of individual "cell memory". This problem is commonly referred to as the memory effect and results in reduced battery life. Therefore, partially recharging a NiCad battery shortens its life. NiCad batteries are in widespread use and will not go away in the immediate future.

3. Nickel hydride (NiHM)

Unlike NiCad batteries, nickel hydride batteries are not susceptible to the memory effect. NiMH batteries are environmentally safer than NiCad types because of the absence of cadium. They have 30 to 40 percent more energy for the same weight, so they have a greater energy density than older NiCad batteries. NiMH batteries cost about four times more than NiCads but have approximately 20 percent more capacity. They last up to four hours before recharging is needed. The price of NiMH batteries is beginning to decline because of the new lithium ion battery available on the market.

4. Lithium polymer

Valence Technology of San Jose, California, is one company developing lithium polymer technology, which uses a solid electrolyte rather than a liquid substance like NiCad and NiMH use. The use of a solid electrolyte makes the batteries lighter, less hazardous to the environment, and hold a charge for a longer period of time. The energy

density is also about 55 percent greater than NiMH. Another advantage of this battery is that it does not suffer from the memory effect. Lithium polymer batteries can be produced at a cost less than NiCad and NiMH batteries. These batteries are currently too large to be practical for portable computer applications.

5. Lithium ion

Lithium ion batteries for subnotebook and notebook computers are the newest, most efficient, and most expensive ones available. The energy density of lithium ion batteries is about 70 percent greater than NiMH batteries. This newest type of battery is already being used in Japan. Sony Corporation of Japan is using lithium ion batteries in one of their video cassette recorders sold exclusively in Japan. Toshiba Corporation includes this type of battery with its Portege notebook computer. Lithium ion batteries are rare in the United States but the market should soon open. (Benson, 1994)

6. Zinc-air

AER Energy Resources, Incorporated of Smyrna, Georgia, is producing an external rechargeable zinc-air battery. The weight (about six pounds) of current zinc-air batteries is still too heavy for portable computers. It measures 12 inches by 6 inches by 3 inches. This type of battery has as much as three times the power of NiMH batteries and can provide power for up to 20 hours before recharging is needed. Energy density is about 180 percent greater than NiMH batteries. Zinc-air technology is about 60 years old, but building a rechargeable battery to fit in notebook computers has yet to be

accomplished. AER and Zenith Data Systems (ZDS) are co-developing a smaller zinc-air

battery to fit inside ZDS notebook computers. (Weber, 1994)

7. Battery Tests

AER Energy Laboratory conducted battery tests (Weber, 1994) using three

similar portable computers: Apple PowerBook 170, Dell 325N, and Texas Instruments

TravelMate 4000.[1] The NiCad battery in the Apple had a computed run time of 2.3 hours,

the TravelMate's NiCad battery lasted 2.5 hours, and the NiMH in the Dell had a run time

of 3.7 hours. The results are depicted in Table C-2. This table is adapted from AER

Energy Resource (Weber, 1994) and shows a comparison of the various battery types.

AER used their zinc-air battery on the same three portables and dramatically

increased the run times on the Apple, Dell, and TI to 15 hours, 10 hours, and 9.0 hours,

respectively. The zinc-air battery is available only externally and is heavy.

	NiCad	NiMH	Lithium Polymer	Lithium Ion	Zinc-air
Energy Density (watt hrs/kg)	40	55	85	95	155
Energy Storage (watt hrs)	35	50	NA	NA	140
Run Time (hours)	2 to 3	2.5 to 4	NA	2 to 2.5	8 to 12
Average Cost (per watt hr)	$0.74	$1.48	NA	$3.00	$0.74
Environmental Hazard	Cadium	NA	Lithium	Lithium	NA

Table C-2 Battery Type Comparison

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[1] AER Energy Laboratory tests were conducted in May 1993 using NiCad and NiMH batteries
furnished with each of the portable computers.

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8. Industry Standard

Duracell Corporation and Toshiba of America Information Systems are jointly developing a battery for notebook computers in hopes to provide an industry standard (Lee, 1993). One battery type already introduced in four experimental sizes uses NiMH technology. If the joint venture is successful, battery prices should decrease. A problem with a venture like this is getting a substantial number of notebook vendor's support and cooperation.

I. NOTEBOOK VENDORS

The vendor or brand name found on a computer does not necessarily represent the company that manufactured it. For instance, Matsushita Corporation of Japan, makes and sells portable computers to Panasonic, Tandy, GRiD, and DEC. The companies purchase the computers from Matsushita with their own brand names on them (Roth, 1993). Likewise, Sharp manufactures about 70 percent of all LCD computer screens that are made for portable computers.

Most vendors provide at least a 12 month warranty on their notebooks. Some warranties are available up to 36 months and vary in cost. Various types and durations of technical support is also available from notebook vendors.

J. RECOMMENDED FEATURES OF A PORTABLE COMPUTER

This section recommends features that are considered essential in shipboard applications of portable computers.

1. Screen Type

The primary types of screen displays are standard liquid crystal display (LCD), passive-matrix, dual-scan, and active-matrix. The later three types are based on LCD concepts. Active-matrix color displays are the most coveted and provide the best visual acuity. Unfortunately they also happen to be the most expensive. Due to tight military budget constraints, a color display may be considered an unnecessary luxury. Until the cost of color displays significantly decrease, a monochrome passive-matrix is the most practical display to use aboard ship.

2. Expansion Slots

The notebook selected should have at least one PCMCIA slot. Most come with a Type II, but a Type III is most desirable. The Type III slot can provide for an additional hard drive or any other device that will fit in a Type I or II (Smarte, 1994). For best versatility and expansion capability, a Type II slot is recommended. Additionally, before buying a PC Card, one should ensure that the card is supported by the notebook in which it is to be installed, and that the Socket Service and Card Service drivers are included.

3. Cursor Positioning Device

A trackball, which is accurate, operates quickly, and saves critical desktop space, is the recommended cursor positioning device on a portable computer used in shipboard applications.

4. Central Processing Unit (CPU)

The best compromise between high performance and low power consumption is a 486SL central processing unit operating on 3.3 volts. The SL chip offers power down features which are essential in saving battery power, while the 486 offers superior windows performance. Most portable computers come with at least 25 MHz processors, but a 33 MHz offers better overall system performance. Therefore, a 486SL/33 is the recommended CPU for a portable computer.

5. Battery Type

NiMH type batteries are safer aboard ship, last longer, and are therefore preferred over NiCad. At least one spare battery and charger should be purchased with the computer.

6. Random Access Memory (RAM)

A minimum of 4 MB RAM should be the base memory in a portable computer. In addition, it should have the ability to be upgraded to at least 8 MB, which provides optimum Windows performance. (Fox, 1994)

7. Internal and External Drives

Hard disk storage should be at least 120 MB. Disk space fills up quickly with modern applications. For example, it takes over 30 MB to store a Microsoft Windows™ based word processor program.

An internal 3.5 inch 1.44 megabyte floppy drive is mandatory because it is needed to load and download software and data to the hard drive.

APPENDIX D: MAES USER'S SURVEY

A.   OVERVIEW

This first section of this appendix provides a brief discussion on surveys and how one can be used gather data about MAES. The discussion is followed by a survey that is written to solicit information from the Fire Control Technicians who use MAES.

B.   USE OF SURVEYS

Surveys are usually more efficient and economical than by directly observing someone performing a task or using a system. However, one disadvantage of using a survey is that the quality of the data (information) gathered depends on the respondent's ability and willingness to cooperate by answering questions.

A survey that is self administered is the next best thing to personal interaction with the respondent. These types of surveys are inexpensive compared to the cost of conducting personal interviews with each respondent. Another advantage of using self administered surveys is that they can be mailed to people who may not normally be accessible, such as personnel aboard U.S. ships stationed in Japan. Mail surveys are the best data collection technique to use when the sampling population is scattered abroad.

Notifying potential respondents before a survey is given to them, and following-up with the respondent are effective ways to improve the response rate. Some evidence concludes that the respondent will be more apt to complete and return a survey if received

by registered mail, has an addressed return envelope included, and if it has official sponsorship. (Kanuk, 1992)

C. MAES SURVEY

This thesis developed a survey to gather important feedback from the users of MAES. (The survey follows this discussion.) The staff of the MK 92 FCS Maintenance School and the technicians aboard the USS SIDES (FFG-14) have copies of the survey.

The technicians using the MAES aboard the USS SIDES are underway conducting operations in the Pacific Ocean and can not be easily accessed. The technicians will complete and mail their responses to the Naval Postgraduate School for compilation before December 1994.

The MAES survey primarily uses rating scale type of questions. Rating scales are useful for the respondent's ability to judge certain items in a question without having to compare it to another similar item. The most common type of rating scale is called the Likert Scale. Two points of scale are all that is needed to ask a rating scale type question. However, the range should be from three to seven points (Emory, 1992). The Likert Scale questions in the MAES survey use five points of scale.

Unknowingly to the respondent, each response may have numeric values assigned to it for later calculation. For example, "Strongly Disagree" may be assigned a value of one, while "Strongly Agree" is assigned the value of five. Statistical analysis may then be conducted on the completed surveys using these values.

As an example, the maintainers of the MAES, can discover what the technicians think about the location of buttons throughout the MAES. The responses can be statistically analyzed by calculating a standard deviation, mean, or variance of the response to a particular question. Is this example, the maintainer can then decide if the buttons need to be relocated.

1. How long have you used a *desktop* personal computer? (Check only one.)

    ___ No experience
    ___ Less than one year
    ___ One to two years
    ___ More than two years

2. How long have you used a *laptop or notebook* personal computer? (Check only one.)

    ___ No experience
    ___ Less than one year
    ___ One to two years
    ___ More than two years

3. Have you ever used a lapheld or laptop personal computer that has a built in mouse or trackball? (Circle only one.)

    True   False   Not Sure

For items 4 and 5, mark only one choice for this survey. If you used more than one type of computer, please ask the facilitator to give you additional copies of the survey.

4. Identify the type of computer you used operating the MK 92 Maintenance Advisor.

    O IBM/Compatible Desktop
    O IBM/Compatible Laptop
    O IBM/Compatible Notebook

5. Identify the type of central processor (CPU) the computer has from your choice in item 4.

    O 286
    O 386SX
    O 386DX
    O 486SX
    O 486DX
    O Don't Know

6.   How comfortable are you with running windows applications on a personal computer? (Circle only one response.)

      O Very Uncomfortable
      O Uncomfortable
      O No Strong Opinion
      O Comfortable
      O Very Comfortable

7.   Check the operating environments in which you have experience using a personal computer. (Check as many items as applicable or None.)

      ___ DOS   ___ Windows
      ___ OS/2   ___ UNIX
      ___ Other (Please Specify)   ___ None

8.   How comfortable were you with using the mouse? (Check only one.)

      O Very Uncomfortable
      O Uncomfortable
      O No Strong Opinion
      O Comfortable
      O Very Comfortable

The items 9 through 12 pertain to how *easy* it was for you to use the MK92 Maintenance Advisor.

9.   It is easy to *understand* what the program wants you to do next. (Check only one.)

      O Very Difficult
      O Difficult
      O No Strong Opinion
      O Easy
      O Very Easy

10.   Rank the *ease of use* of the program. (Check only one.)

      O Very Difficult
      O Difficult
      O No Strong Opinion
      O Easy
      O Very Easy

11.   On-line help is available when using the program. (Check only one.)

    O   Very sufficient
    O   Sufficient
    O   No Strong Opinion
    O   Insufficient
    O   Very Insufficient

12.   Guesswork is needed to operate most of the program. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

Items 13 through 18 pertain to your ability to *navigate* through the program.

13.   Was it difficult to *exit* the program? (Check only one.)

    O   Very Difficult
    O   Difficult
    O   No Strong Opinion
    O   Easy
    O   Very Easy

14.   Was it easy to *exit* display windows in the program? (Check only one.)

    O   Very Difficult
    O   Difficult
    O   No Strong Opinion
    O   Easy
    O   Very Easy

15.   Was it easy to *back-up* to a previous screen? (Check only one.)

    O   Very Difficult
    O   Difficult
    O   No Strong Opinion
    O   Easy
    O   Very Easy

16.   What is the relevance of the program's ability to *back-up* to a previous screen. (Check only one.)

    O   Very Relevant
    O   Relevant
    O   No Strong Opinion
    O   Irrelevant
    O   Very Irrelevant

17.   How often did you feel *lost* in the program? (Check only one.)

    O   Very Often
    O   Often
    O   No Strong Opinion
    O   Seldom
    O   Very Seldom

18.   The program's display screens gave you sufficient information. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

Items 19 through 21 address your options available and physical actions while using the MK 92 Maintenance Advisor.

19.   There *were too many* options on the screens. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

20.   There were *too few* options on the screens. (Check only one.)

    O   Strongly Disagree
    O   Disagree
    O   No Strong Opinion
    O   Agree
    O   Strongly Agree

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21. The program *required* you to perform too many actions. (Check only one.)

    O Strongly Agree
    O Agree
    O No Strong Opinion
    O Disagree
    O Strongly Disagree

Items 22 to 24 deal with your perception of the program's ability to keep track of where you are in the program and relay the information to you.

22. The program kept track of your actions. (Check only one.)

    O Strongly Agree
    O Agree
    O No Strong Opinion
    O Disagree
    O Strongly Disagree

23. The Logbook is useful for viewing your previous paths. (Check only one.)

    O Strongly Agree
    O Agree
    O No Strong Opinion
    O Disagree
    O Strongly Disagree

24. Was your path in the program represented to you? (Check only one.)

    O Very Poorly Represented
    O Poorly Represented
    O No Strong Opinion
    O Well Represented
    O Very Well Represented

Items 25 through 43 pertain with your perception of how the screen looks.

25. There is an adequate amount of *graphics* in the program window screens. (Check only one.)

    O Strongly Agree
    O Agree
    O No Strong Opinion
    O Disagree
    O Strongly Disagree

26.   The *text* was easy to read. (Check only one.)

    ○ Strongly Agree
    ○ Agree
    ○ No Strong Opinion
    ○ Disagree
    ○ Strongly Disagree

27.   Was the text *too small*? (Check only one.)

    ○ Yes
    ○ No

28.   Was there *too much* text on the screen? (Check only one.)

    ○ Yes
    ○ No

29.   The *font* style of the text is appropriate for a diagnostic computer program. (Check only one.)

    ○ Strongly Disagree
    ○ Disagree
    ○ No Strong Opinion
    ○ Agree
    ○ Strongly Agree

30.   The *font* style of the text is consistent. (Check only one.)

    ○ Strongly Disagree
    ○ Disagree
    ○ No Strong Opinion
    ○ Agree
    ○ Strongly Agree

31.   The *text* was consistently located in the same area throughout the program. (Check only one.)

    ○ Strongly Disagree
    ○ Disagree
    ○ No Strong Opinion
    ○ Agree
    ○ Strongly Agree

32.   *Buttons* were consistently located in the same location throughout the program. (Check only one.)

        O   Strongly Disagree
        O   Disagree
        O   No Strong Opinion
        O   Agree
        O   Strongly Agree

33.   Did the button labels correspond to their applicable function? (Check only one.)

        O   Very Suitable
        O   Suitable
        O   No Strong Opinion
        O   Unsuitable
        O   Very Unsuitable

34.   Were the button names meaningful? (Check only one.)

        O   Very Meaningful
        O   Meaningful
        O   No Strong Opinion
        O   Unmeaningful
        O   Very Unmeaningful

35.   Were the color of the *buttons* were meaningful? (Check only one.)

        O   Very Meaningful
        O   Meaningful
        O   No Strong Opinion
        O   Unmeaningful
        O   Very Unmeaningful

36.   The size of the *buttons* were the correct size. (Check only one.)

        O   Strongly Agree
        O   Agree
        O   No Strong Opinion
        O   Disagree
        O   Strongly Disagree

37.   The *buttons* were easy to read. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

38.   The *buttons* were located in appropriate locations on the screen. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

Answer items 39 and 40 only if you have a black and white or monochrome monitor.

39.   The screen shadings were appropriate. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

40.   The screen shadings were easy to differentiate. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

Answer items 41 and 42 only if you have a color monitor.

41.   The screen colors were stimulating. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

42. The screen colors were appropriate. (Check only one.)

 O Strongly Agree
 O Agree
 O No Strong Opinion
 O Disagree
 O Strongly Disagree

43. The mixture of screen colors were too numerous. (Check only one.)

 O Strongly Agree
 O Agree
 O No Strong Opinion
 O Disagree
 O Strongly Disagree

Items 44 through 49 deal with your knowledge of the topics presented by the program.

44. You knew the whereabouts of the components referenced by the program. (Check only one.)

 O Strongly Agree
 O Agree
 O No Strong Opinion
 O Disagree
 O Strongly Disagree

45. You knew how to replace the faulty component. (Check only one.)

 O Strongly Agree
 O Agree
 O No Strong Opinion
 O Disagree
 O Strongly Disagree

46. You knew where to go when the program instructed you to go do something. (Check only one.)

 O Strongly Agree
 O Agree
 O No Strong Opinion
 O Disagree
 O Strongly Disagree

47.   The information on the screen was too technical. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

48.   The information was presented in an understandable format. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

49.   The information on the screen was at a knowledge level for all technicians in your work center. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

The next two items deal with your opinion on multi-media upgrades to the program.

50.   A program revision to include *sound* would be beneficial to the user. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

51.   A program revision to include *full-motion video* would be beneficial to the user. (Check only one.)

    O   Strongly Agree
    O   Agree
    O   No Strong Opinion
    O   Disagree
    O   Strongly Disagree

52. Overall artistic aspects of the program were pleasing. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

The remainder of the items deal with how you perceive the overall functionality of the progam.

53. The program led you to the correct faulty component. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

54. The program led you to the right area of the system failure. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

55. The program provided useful raining to the user. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

56. The program saved time finding the casualty. (Check only one.)

   O Strongly Agree
   O Agree
   O No Strong Opinion
   O Disagree
   O Strongly Disagree

57.	Parts information given by the program was correct. (Check only one.)

○	Strongly Agree
○	Agree
○	No Strong Opinion
○	Disagree
○	Strongly Disagree

58.	Enough parts information is given to order the correct part. (Check only one.)

○	Strongly Agree
○	Agree
○	No Strong Opinion
○	Disagree
○	Strongly Disagree

59.	The "How" function provided enough help assistance to conduct the procedure in question. (Check only one.)

○	Strongly Agree
○	Agree
○	No Strong Opinion
○	Disagree
○	Strongly Disagree

60.	The "Why" function provided suitable help explanations. (Check only one.)

○	Strongly Agree
○	Agree
○	No Strong Opinion
○	Disagree
○	Strongly Disagree

61.	The Logbook feature was a useful feature for taking notes. (Check only one.)

○	Strongly Agree
○	Agree
○	No Strong Opinion
○	Disagree
○	Strongly Disagree

62. The Logbook feature was easy to use. (Check only one.)

- O Strongly Agree
- O Agree
- O No Strong Opinion
- O Disagree
- O Strongly Disagree

63. Performance and Calibration Modules had little differences in appearance. (Check only one.)

- O Strongly Agree
- O Agree
- O No Strong Opinion
- O Disagree
- O Strongly Disagree

64. Performance and Calibration Modules had little differences in functions. (Check only one.)

- O Strongly Agree
- O Agree
- O No Strong Opinion
- O Disagree
- O Strongly Disagree

65. Once the fault is located during troubleshooting, part information is *easy* to obtain. (Check only one response.)

- O Strongly Agree
- O Agree
- O No Strong Opinion
- O Disagree

Thank you for giving up your valuable time to complete this survey. Please return the completed questionnaire to your supervisor.

APPENDIX E: MAES PROTOTYPE 1.0 INSTALLATION FILES

This Appendix lists the contents of the three primary script files required to install

the MAES Prototype 1.0 using INSTALIT For Windows 4.5 software installation tool.

A.   MAES_1_0.INF SCRIPT FILE

The MAES_1_0.inf script file tells INSTALIT what to do and what to do with

MAES product files that are compress into libraries.

```
DefineVariables
Number [ReturnVal1]
Number [ReturnVal2]
number [ReturnVal3]
Number [ErrCount]
Directory [windir]
Directory [winsdir]
Logical [EnKeyb]
Logical [NetAvail]
Logical [MathPres]
Logical [CDAvail]
Text [DispType]
Number [XMSAvail]
Number [ExtmemPagesActive]
Number [ExtmemPagesAvail]
Number [ExtMemAvail]
Number [ExtMemPres]
Number [ExpMempgavail]
Number [ExpMempgactive]

Text [osver]
Text [DosVer]
Text [EmsVer]

Text [ProdExecutable]
Text [GroupTitle]
```

```
Text [GroupFile]
Text [ExistingGroupName]
Text [InstDir]

Text [FactsIconF]

Text [IconTitle]
Text [IconFile]

EndDefineVariables

[EnKeyb] := NoCharacter
[NetAvail] := NoCharacter
[MathPres] := NoCharacter
[CDAvail] := NoCharacter

Do SetupDisplay
Do CheckHardware

if [errcount] > 1
Dialog UseHeader "Encountered Some Problems"
.L Our installation has encountered the following problems,
.L you can continue to install or exit installation.
[Array1][1]
[Array1][2]
[Array1][3]
[Array1][4]
[Array1][5]
[Array1][6]
[Array1][7]
EndDialog
endif
ShowBitMap 1 @xy(1,1)

:start

DialogBox  150  80  UseHeader  "Installing  MAES  Prototype  1.0"  Returns
[ReturnVal1] BlackOnLightGray
Font "Helv" 8
GroupBox @xy(5,4) 135 70 "Select Option"
RadioButtonGroup Uses [ReturnVal2]
RadioButton @xy(10,17) 120 12 "&Install MAES Prototype 1.0"
RadioButton @xy(10,30) 120 12 "&Hardware Summary"
```

```
RadioButton @xy(10,43) 120 12 "&Exit Installation"
PushButton @xy(60,55) 38 14 "OK" OK
EndDialogBox

if [ReturnVal2] = 1
Do Install
goto start
endif

if [ReturnVal2] = 2
Do HardwareSum
Goto start
endif

if [ReturnVal2] = 3
SoLong
Endif

if [RetrunVal2] = 0
Dialog
Click on one of the option buttons.
EndDialog
Goto start
Enddialog
endif

Procedure SetupDisplay
SetDefaultBitMap Off
SetBackGroundColor 0 0 64 191 64 0 TopToBottom

SetPopupAttrTo YellowOnBlue
if FileIsInLibrary ship.bmp
if FIleExists ShadowDirectory\ship.bmp
DeleteFiles from ShadowDirectory Quietly
ship.bmp
EndDeletefiles
endif

QueFiles to ShadowDirectory noinquiry
ship.bmp
EndQueFiles
GetQuedFiles Quietly
LoadBitmap 1 ShadowDirectory\ship.bmp
```

```
endif
ShowWindow maximized

EndProcedure

Procedure Install
[InstallationDirectory] := MAES
DetermineInstallationDrive
DetermineInstallationDirectory installationdrive:\[installationdirectory]
QueAllFiles
GetQuedFiles
ModifyAutoexecBat
AddPathComponent installationdrive:\MAES At Beginning
EndModifyAutoexecBat
ChangeDirectoryto [InstallationDirectory]
[ProdExecutable] := [InstallationDirectory]\runadept.exe maes_1.adp
[GroupTitle]  := MK 92
[InstDir]     := [InstallationDirectory]
[IconFile]    := maes.ico

[IconTitle]   := MAES Prototype 1.0

:top
DialogBox 150 80 UseHeader "Install Icon" Returns [Number1]
Font "Helv" 8
RadioButtonGroup Uses [Number2]
RadioButton @xy(6,6) 150 12 "We can install Icon in an &existing group"
RadioButton @xy(6,20) 150 12 "Or we can install Icon in a &new group"
RadioButton @xy(6,34) 150 12 "Or we can &skip this part"
PushButton @xy(60,60) 38 14 "OK" OK
EndDialogBox

if [Number2] = 1
[Array2] := GetProgramManagerGroupNames

DialogBox 177 70 UseHeader "Choose Group to Install Icon Into" GreenOnBlack
Returns [Number7]
ListBox @xy(15,7) 120 30 Uses [String1] LoadWith [Array2]  Border
PushButton @xy(60,55) 38 14 "OK" OK
EndDialogBox
[ExistingGroupName] := [String1]
if [ExistingGroupName] = BlankString
popup no group selected, not installing icon
```

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```
else
ProgramManagerDDE
CreateGroup([ExistingGroupName])
AddItem([ProdExecutable],[IconTitle],[InstallationDirectory]\[IconFile])

EndProgramManagerDDE
endif
endif

if [number2] = 2
ProgramManagerDDE
CreateGroup(MK 92)
AddItem([ProdExecutable],[IconTitle],[InstallationDirectory]\[IconFile])
EndProgramManagerDDE
endif

if [Number2] = 3
popup not installing icon
endif
EndProcedure

Procedure CheckHardware
[Number3] := 1

if VGA
[DispType] := VGA
endif

if CGA
[DispType] := CGA
endif

if EGA
[DispType] := EGA
endif

if [DispType] = BlankString
[Array1][[number3]] := Your Display adapter must be EGA or better.
IncrementNumber [number3]
endif

[windir] := [WindowsDirectory]
[winsdir] := [WindowsSystemDirectory]
```

```
[ExtmemPagesActive] := ExtendedMemoryPagesActive
[ExtmemPagesAvail] := ExtendedMemoryPagesAvailable
[ExtMemAvail] := ExtendedMemoryAvailable
[ExtMemPres] := ExtendedMemoryPresent
[ExpMempgAvail] := ExpandedMemoryPagesAvailable
[ExpMempgActive] := ExpandedMemoryPagesActive
[osver] := OSVersion
[DosVer] := DOSVersion
[EmsVer] := EMSVersion

if [DOSVer] @ 5.0
[Array1][[number3]] := You must have a DOS version of at least 5.0 or more
IncrementNumber [number3]
endif

[Errcount] := [Number3]

EndProcedure


Procedure HardwareSum
Dialog
Display Type : [DispType]
DOS Version  : [DosVer]
Extended Memory Available : [ExtMemAvail]
Extended Memory Present : [ExtMemPres]
Extended Memory Pages Active : [ExtMemPagesActive]
Extended Memory Pages Available : [ExtMemPagesAvail]
Expanded Memory Pages Available : [ExpmempgAvail]
Expanded Memory Pages Active    : [ExpMempgactive]

Windows Directory  : [windir]
Windows System Directory : [winsdir]
EndDialog

EndProcedure
```

B. MAES_1_0.PVD SCRIPT FILE

The MAES_1_0.pvd script file, a non-procedural file, is a product version description (PVD) file which describes the contents of the MAES product release and some information about its installation.

```
[ProductVersionDescription]
[productname] MAES Prototype
[Productversion] 1.0
[script] MAES_1_0.INF
[Installer] INSTALIT.EXE as INSTALIT.EXE
[NewSeries] "MAES ?" MAES_1_0 MAES_?
[UseDirectory] c:\maes
[addtree] [excludefiles]
[EndProductVersionDescription]
```

C. MAES_1_0.SDF SCRIPT FILE

The MAES_1_0.sdf script file is a script data file (SDF) which contains the script that allows the user to control the installation process by answering questions.

```
LoadBMP = 1
PvlpickorTree = 1
Group_TitleName = MK 92
Group_FName =
Group_FileName =
Icon_TitleName = MAES Prototype 1.0
Icon_FileName = maes.ico
chkextmem = 0
chkexpmempg = 0
chkEnhanced = 0
minextmem = 0
minexpmem = 0
chkMathCo = 0
chkfornet = 0
cdpres = 0
ModConfig = 0
Showbitmapoption = 0
```

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```
instd = MAES
prodexe = runadept.exe maes_1.adp
minimumDOSVer = 5.0
PVDName = MAES_1_0.pvd
PVLName = MAES_1_0.pvl
VersionNumber = 1.0
ScriptName1 = MAES_1_0.INF
LibraryName = MAES_1_0
DiskName = MAES
ExcludeTheseFiles =
DriveToBuildDisksTo = A:
ProductNam = MAES Prototype
FilesDirectory = c:\maes
VolumeLabel =
MinimumBuffersSetting = 10
MinimumFilesSetting = 10
DefaultBitMapSetting = Off
DefaultPopupAttributeSetting = SetPopupAttrTo YellowOnBlue
SetBackgroundScreenColor = SetBackGroundColor 0 0 64 191 64 0 TopToBottom
LoadBitMapIfAny =
Location = Beginning
InstallDir = MAES Prototype
AddInstallationDirToPath = 1
InstallIcon = 1
Group_TitleName = MK 92
ScriptOptionsText = Select Option
ScriptHeaderText = Installing MAES Prototype 1.0
IncludeIconFile = ,[InstallationDirectory]\[IconFile]
DefaultBitMapName = ship.bmp
```

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